COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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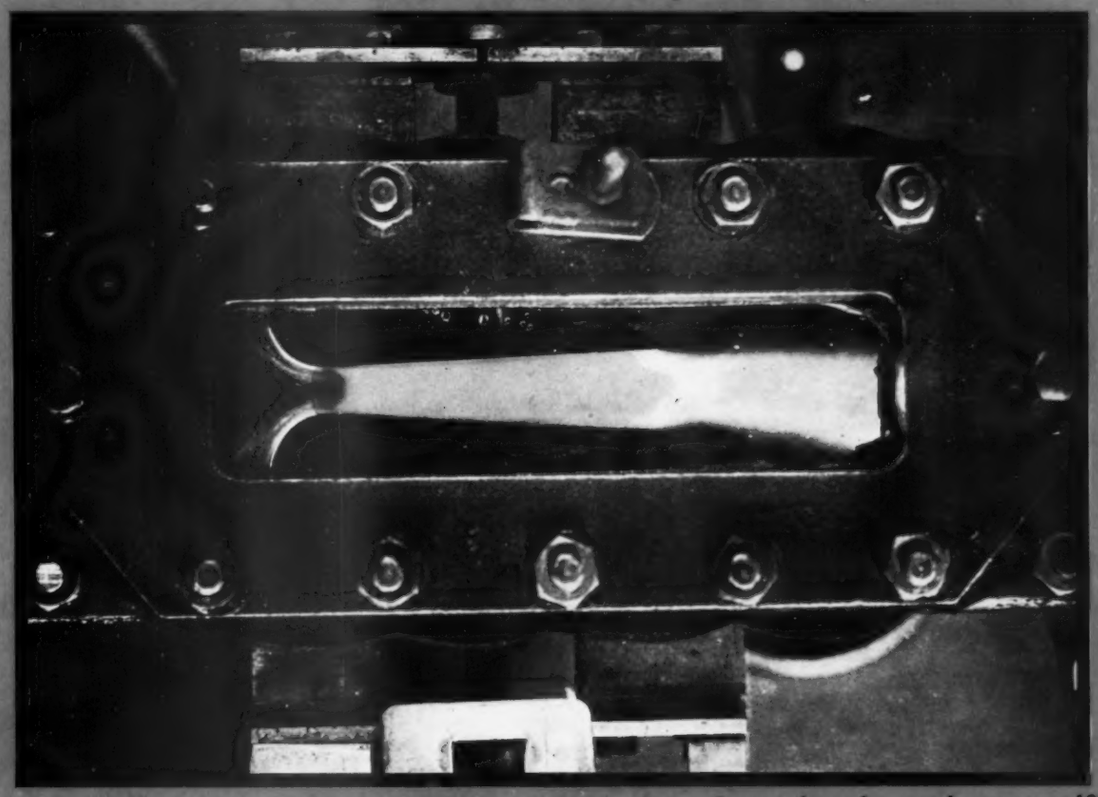


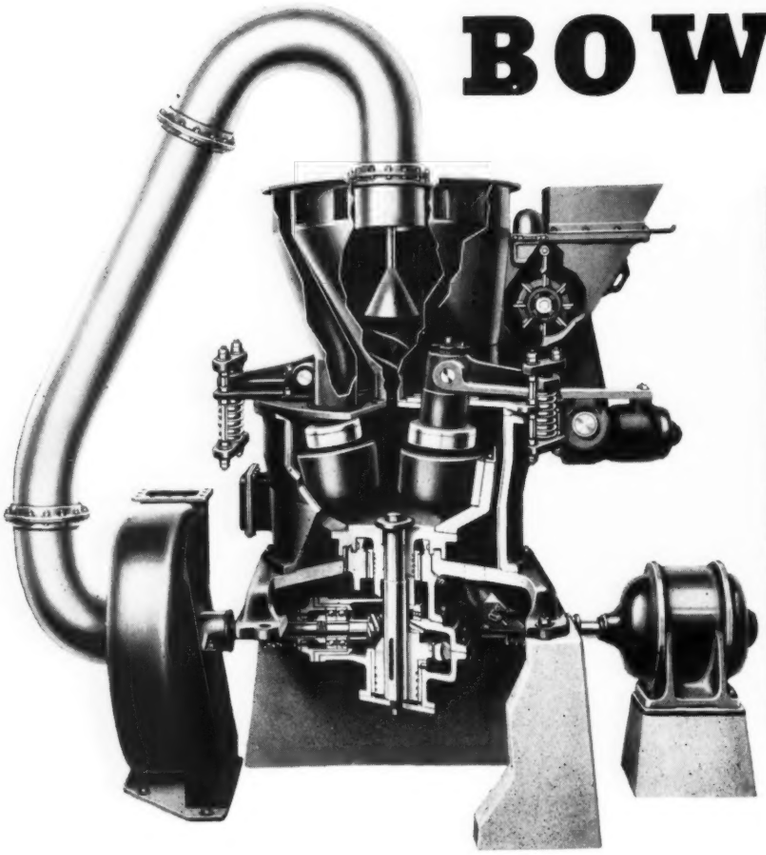
Steam flowing through a nozzle; see page 16

Observations of Flowing Steam

Central Station Flow Diagrams

Creep and Corrosion Discussed at International Congress

The C-E RAYMOND BOWL MILL



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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME EIGHT NUMBER ELEVEN

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GENERAL ELECTRIC

EDITORIAL

Advice to Engineering Graduates

Next month a new batch of engineering graduates will be going forth to take their places in industry. The opportunities ahead of them are more auspicious than have obtained for some years, for the engineering schools report that the demand for graduates exceeds the supply. Herein, however, lurks danger for those not prepared and willing to make the best use of their opportunities, for it is the necessity of overcoming adversity that usually brings out the best in the young engineer. Nevertheless, the experiences of those who have gone before are usually both welcome and helpful to those anxious to profit thereby.

Especially pertinent at this time is the substance of an informal talk which R. M. Gates, Vice President of Combustion Engineering Company, Inc., gave before a large group of seniors at the A.S.M.E. Southern Student Meeting at Chattanooga on April 19. Mr. Gates chose a broad approach to his subject in that he did not attempt to impose his own views on the young men, but rather, to serve as the medium of conveying the views of numerous successful engineers now engaged in active practice. To this end he sent letters to over forty such men, young as well as older engineers, requesting replies to two questions, namely: (1) *What was the best and most helpful advice obtained at or near graduation from school?* and (2) *Looking backward, what advice do you wish you had received at the time of graduation?*

All replied. Many indicated that they, in turn, had consulted their associates, so that the net result covered the views of many more than the orginal forty men solicited for opinions. The answers were most illuminating—not alone for those just about to enter the engineering field but also for those already in it. There was a wide diversity of advice as well as some duplication which, however, served to emphasize its importance. Space does not permit here reproducing all the replies, but a few of the more important are grouped and summarized. Here are some pertaining to the first question:

Absorb fundamentals; do not try to remember everything learned in college but know where to get the information when needed.

Use your schooling as a start to further study in order to keep abreast of developments in the field.

Following graduation take a job in the shop or in construction work in order to learn how equipment is made and put together, and to develop a common-sense view of practical versus theoretical ideas.

Avoid giving the impression of knowing too much when entering upon a job.

Learn how to sell yourself but be sure you have the necessary qualifications and determination to make good.

Observe facts, and reason from them to see the broad problem, even though you may be concerned with details. In this way you will be training yourself for a bigger position.

Set a high goal; someone must fill the responsible positions and it may as well be you; but remember that there are more positions paying top salaries than there are men properly qualified to fill them.

Do not begin by working for relatives or close personal friends.

There were fewer answers to the first question than to the second which indicated either that little advice had been given prior to graduation or that it had not been grasped with sufficient force to permit its retention. As might be expected, the more experienced engineers were more prolific in their answers to the second question, although many excellent suggestions also came from the younger men. Some of the replies to the second question were, in substance, as follows:

It would have been most helpful before leaving college to have been given a better idea of what constituted work in various branches of mechanical engineering and shown how the college courses fitted into the requirements of practice; also something as to the outlook in these fields.

Information on how engineering equipment is purchased and the procedure involved in drawing up proposals and specifications would have been helpful.

Avoid specialization too early, especially that which is not applicable to a number of different industries. Change jobs in the first few years as often as may be necessary to acquire needed experience, regardless of remuneration. To this end, defer assuming family obligations.

Acquire initiative and imagination.

Endeavor to analyze your qualifications with an unbiased mind and then go after the job you believe you can fill.

Approach engineering problems from the angle of simplicity and common sense and do not permit their analyses to become involved.

Depend upon yourself and don't go to your superior to solve your problems. Be sure to have all the facts and a solution ready when you go to him.

Acquire the habit of selective reading to broaden your knowledge.

The most difficult problems in engineering are those dealing with the human element. Engineering problems respond to well-known laws, but humans do not. Avoid being sensitive or hot-headed. Cultivate the habit of seeing the other fellow's point of view and listen to all suggestions—some may have merit. Remember that patience is as essential as ability. It is especially important to know what the workmen are thinking about, and why.

Learn how to make and keep friends. You are known by your friends, even though you may not know all of them.

One line of endeavor is only a cog in the wheels of progress and seldom sufficient unto itself. Hence, an engineering task can be complete only with the aid of financing, construction, accounting, etc., all of which requires cooperation with others, not only in your particular line, but in complementary lines as well. In this connection it is usually necessary to compromise between engineering considerations and financial considerations—that is, to view the economics of the problem.

Join your professional engineering society and take part in its activities.

As distinguished from the advice usually contained in a Commencement Address, which almost invariably reflects the experience and abstract thinking of a single individual, the foregoing survey represents a cross-section of opinion from engineers of all ages and a wide diversity of experience. Some of the replies were from men eminently successful in their particular lines; others, it would appear, represent what the writers believe might have carried them further; and those from the younger men represent what they have already discovered to be essential to the attainment of advancement in the engineering field.

Observations of Flowing Steam

By JOHN I. YELLOTT

Assistant Professor of Mechanical Engineering, Stevens Institute of Technology, Hoboken, N. J.

By means of an adjustable nozzle, having a glass top through which a beam of light was passed, the steam jet was studied and the point of condensation determined for different angles of divergence. The minute droplets formed by the condensing steam break up the light into its various colors and thus permit further analysis of just what goes on within the nozzle.

STEAM flowing through a glass-topped nozzle is the subject of the color photograph reproduced on the cover of this issue of COMBUSTION. Dry steam is actually invisible, since it is as transparent as air, but as it expands through a nozzle a vast number of extremely minute water droplets form when condensation begins. These droplets pervade the entire stream and when it is properly illuminated the stream becomes visible. Thus, for example, the jet can be seen to detach itself from the wall or to expand beyond the exit of the nozzle. Blue is the predominating color of the light which is scattered by the droplets of water in the jet, indicating that the radius of the droplets is small compared to the wavelength of light. Under certain conditions, however, the blue light gives way to other colors, some caused by changes in the water drops as they pass through the nozzle, others by changes in the manner in which the light is observed.

The April 1937 issue of the *Transactions* of the American Society of Mechanical Engineers contains a detailed description of the apparatus with which these pictures were obtained, as well as a quantitative statement of the results. The following discussion will be confined to the method of observing the flowing steam and the qualitative results to which the method leads.

In 1931 the writer, then a student of Prof. A. G. Christie at the Johns Hopkins University, undertook the study of supersaturation or undercooling of steam in nozzles. After reviewing the methods of attack which others had employed for the same problem, it seemed probable that the best results would be obtained with the optical method devised by Stodola and mentioned in his monumental work on the steam turbine. Accordingly, an apparatus was constructed similar to that shown diagrammatically in Fig. 1. A nozzle assembly *J* was mounted between two tees which were provided with ports so that an intense beam of light from a carbon arc could be directed along the axis of the nozzle. The nozzle itself was rectangular in cross-section, the sides being formed by appropriately shaped brass blocks bolted to the walls of the cast-iron channel. The top

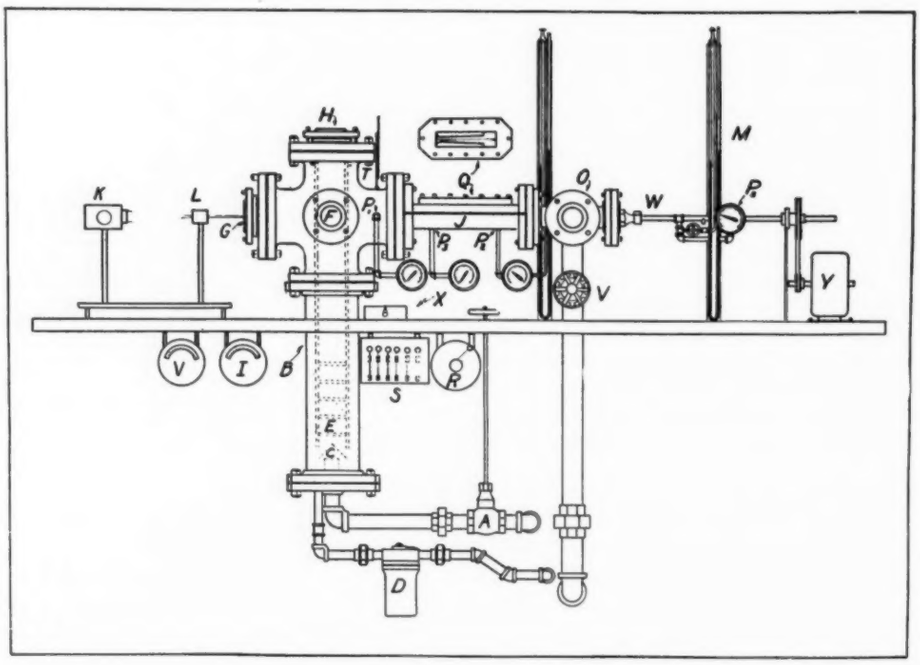


Fig. 1—Diagram of steam-flow apparatus upon which the tests were conducted

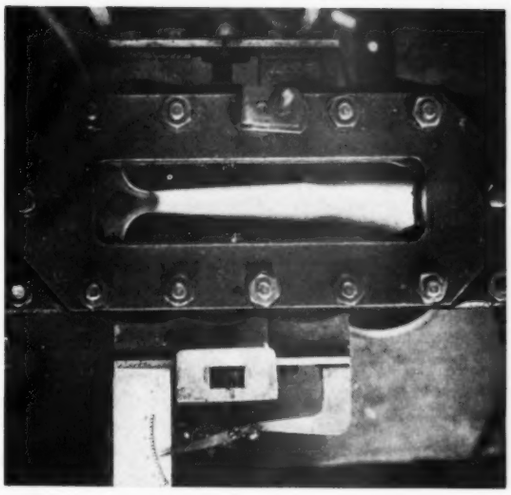


Fig. 2—Top view of nozzle

Steam entering at 40 lb per sq in. abs, wet, back pressure 15 lb abs, angle of divergence 5½ deg, slightly over-expanding. Flow from left to right.

of the nozzle was formed by a $^5/_8$ in. plate of glass which was held down by rubber gaskets and the cover plate Q. Taps were provided at P_3 and P_2 for measuring the pressure before and after the nozzle, while the initial temperature was measured by a thermometer located in a well in the high-pressure tee. Light from the arc K was focussed by the lens L through the port G along the axis of the nozzle. A search tube W was mounted on the low-pressure end of the apparatus so that static pressures could be measured at any point along the axis of the nozzle.

When the apparatus was put into operation it was found that the high-pressure end of the nozzle channel was quite transparent and apparently empty, while just beyond the throat a dense blue cloud appeared (see Fig. 2). The point of origin of the cloud was very distinct, and the static pressure could readily be measured at this point by a mercury column attached to the search tube. As a result of a series of such measurements, the initial conditions being varied over as wide a range as possible, it was found that expanding steam does not begin to condense as soon as the saturation line is reached. Instead, the steam continues to expand as in the superheated region, thus becoming supersaturated. If the expansion is very rapid, condensation will be delayed until the steam reaches a condition indicated approximately by the 4.5 per cent moisture line on the Mollier Diagram. This line is called the "Wilson Line," and steam cannot expand beyond it without beginning to condense.

After leaving the Johns Hopkins University, the writer built a new apparatus at the University of Rochester, similar to the original except that crosses were used instead of tees so that one might observe the steam as it entered and left the apparatus. With this equipment it was found that the moisture in wet steam could readily be seen. Likewise, a number of interesting optical phenomena were encountered which, for various reasons, had not been observed with the original apparatus.

In 1934 the writer became a member of the faculty of Stevens Institute of Technology, and a new apparatus was again constructed, a diagram of which is shown in Fig. 1. This was essentially the same as those previously constructed except that another port was added in the side of the high-pressure cross at F. A simple but effective electrical superheater was installed at E, and a motor was provided for moving the search tube. The most important addition to the equipment is the variable nozzle, a photograph of which is shown in Fig. 2. Designed by R. Z. Hague, Stevens '37, the nozzle is so constructed that by rotating a handwheel the angle of divergence of the nozzle can be varied from +16 deg to −4 deg. A dial and indicator are provided by which the angle can be determined. The condensation of steam in parallel and converging streams is now being studied with this nozzle.

As in most research work, this study of the condensation of flowing steam has yielded a number of interesting byproducts. Of these the most valuable is the fact that the minute droplets into which the steam condenses also make the stream visible. The optical basis of this phenomenon is the well-known fact that a beam of light passing through a cloud of small particles is scattered by them, with the particles acting as secondary sources of light. There is no lower limit to the size of particles which can be revealed by this process, for it has been found that even molecules produce perceptible scattering. The intensity of the scattered light varies directly as the sixth power of the radius of the particles, so water drops composed of even a few molecules might be ex-

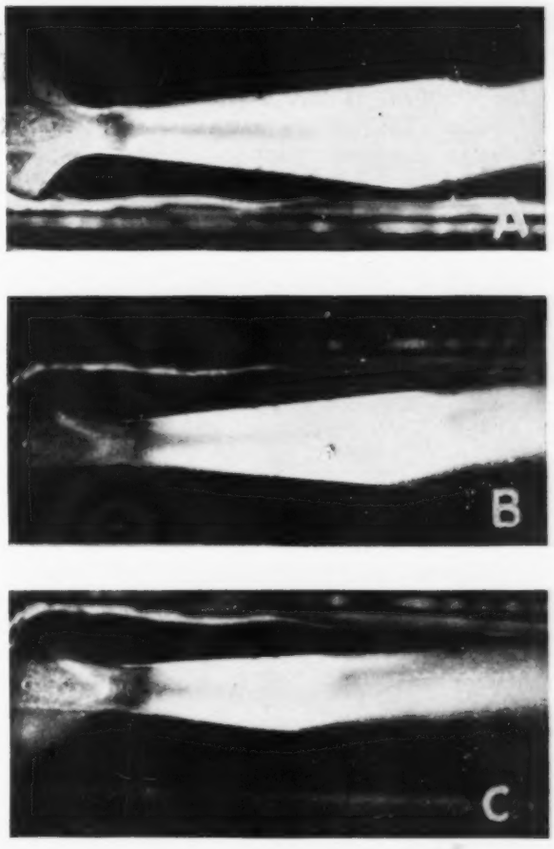


Fig. 3—Steam breaking away from side of nozzle

Initial condition 40 lb per sq in. abs, saturated.
(*A*) Back pressure 7 lb abs.
(*B*) Back pressure 12 lb abs.
(*C*) Back pressure 14 lb abs. Nozzle angle 10 deg.

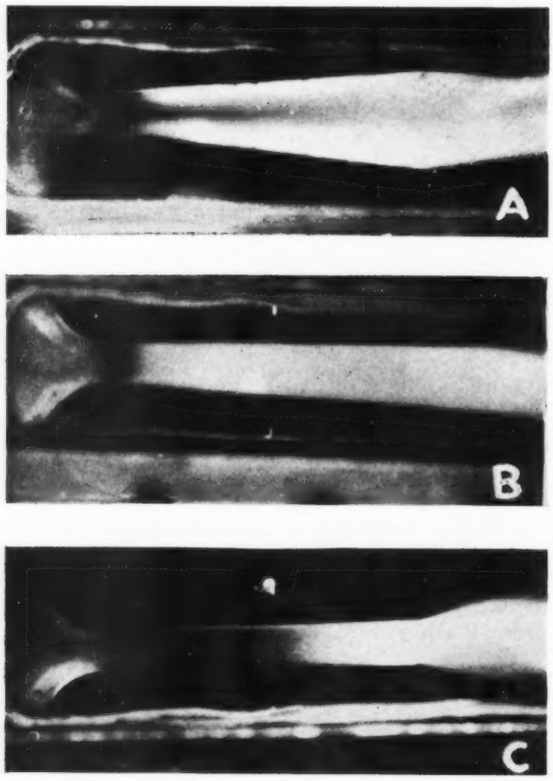


Fig. 4—Effect of varying nozzle angle

Initial condition 40 lb per sq in. abs, saturated. Back pressure 10 lb.
(*A*) Angle set at 8 deg, over-expanding, recompression at exit.
(*B*) Angle set at 4 deg, stream leaves correctly without shock.
(*C*) Angle set at 2 deg, under-expanding, steam expands beyond exit.

pected to scatter light of considerable intensity. Thus, as in the ultra-microscope, particles smaller than the wavelength of light can be traced, although the individual particles cannot be seen.

The nature of scattered light is dependent upon the particles as well as upon the light falling on them. If their diameter is small compared to the wavelength of light, the scattered light will be blue in color and partially plane polarized. The intensity of the light and the extent of the polarization depend upon the angle at which the light is observed. The scattered light can best be seen if the line of observation is perpendicular to the direction of the incident light, for then the view is not confused by the transmitted light. At this angle, also, the polarization is almost complete. If the particles are large compared to the wavelength of light, however, the color and the polarization of the scattered light will change very decidedly, thus providing a clue to the size of the particles.

When one observes the steam jet in this apparatus, the point of origin appears to be quite stationary, although the stream velocity at this point must be greater than the velocity of sound. (The Wilson Line is so located that for low-pressure steam the condensation pressure is always less than one-half of the pressure at which the expansion started.) This apparent lack of motion is explained by the fact that as each drop forms and passes along the nozzle it is followed by another which has formed at exactly the same point. The jet as a whole can often be seen to move from one side of the nozzle to the other, but the beginning of the jet apparently remains fixed.

The photographs with which this discussion is illustrated were taken by mounting a camera directly above the apparatus. Fig. 2 is thus a bird's-eye view of the situation, with the camera mounted high enough to permit the entire nozzle to be seen. The black-and-white photographs were taken by the writer with an f:4.5 Voightlander camera, using panchromatic film with exposures of $^1/_2$ to $^1/_{10}$ sec. The color photograph on the cover was taken by J. H. Lichtenstein, Stevens '37, using Kodachrome A in an f: 2 Leica with exposures of one to two seconds.

Sixteen millimeter moving pictures have been taken by John A. Davis of Stevens Institute, on both black-and-white and Kodachrome, using an f:1.9 Bell and Howell camera operating at 8 frames per second. Pictures of the water drops entering with the steam were taken through port *F*, Fig. 1, using a Cine-Kodak Special at about 4 frames per second.

The first and perhaps the most interesting phenomenon which was revealed by this method of observing flowing steam was the breaking away of the stream from the side of the nozzle. When the angle of divergence of a nozzle is too great, or when the back pressure is too high, the flow cannot fill the nozzle and the stream breaks away from the wall. This breaking away is quite unstable, and the jet can frequently be seen to jump from one side of the nozzle to the other. Fig. 3 shows a series of photographs taken with a constant nozzle angle of 10 deg., and an initial pressure of 40 lb per sq in. abs, saturated. When the back pressure is set at 7 lb abs, the jet breaks away just before it reaches the end of the nozzle (*A*). When the back pressure is raised to 12 lb abs, the jet looses contact earlier (*B*), and at 14 lb abs the loss of contact occurs still closer to the throat (*C*).

Measurements made with the search tube under these conditions show that the static pressure in the nozzle drops well below the back pressure. It is interesting to note that the flow depends upon the throat pressure,

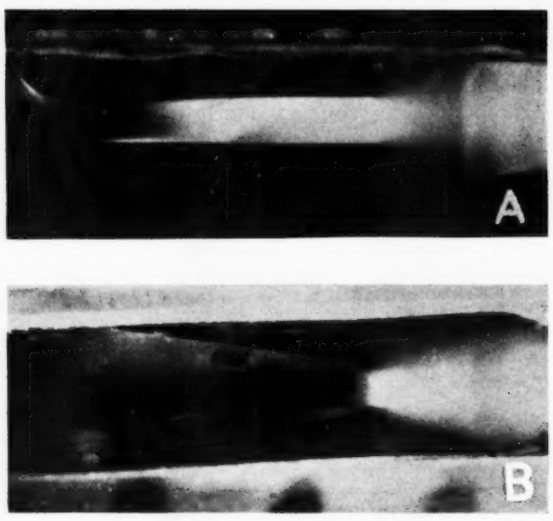


Fig. 5—Effect upon condensation of superheating entering steam

Nozzle angle 2 deg, back pressure 7 lb per sq in. abs.
(*A*) Initial conditions 40 lb abs, wet. Condensation occurs within nozzle; moisture entering with steam reveals eddies beyond nozzle.
(*B*) Initial conditions 40 lb abs, 15 F superheat; condensation only beyond nozzle.

which can remain at the critical value although the back pressure may be raised to within a few pounds of the initial pressure. If the back pressure is sufficiently high so that during the recompression the steam again reaches the pressure at which condensation took place, a dark spot appears in the nozzle. This absence of light is probably caused by the re-evaporation of most of the droplets of moisture. Likewise, the pressure distribution across the jet is frequently non-uniform, and dark bands are present, indicating that the pressure has not fallen low enough to allow condensation to take place in that portion of the jet.

The related phenomena of over- and under-expansion have been investigated by means of the variable nozzle mentioned above. Fig. 4 shows a series of photographs taken with an initial pressure of 40 lb per sq in. abs, saturated and a back pressure of 10 lb abs. When the angle was set at 8 deg, over-expansion occurred and a compression wave was set up at the end of the nozzle (*A*). The stream can be seen to converge beyond the exit of the nozzle. When the angle was reduced to 4 deg the jet flowed correctly, with neither waves nor changes of direction (*B*). When the angle was reduced to 2 deg, under-expansion was present and a lateral expansion took place beyond the nozzle (*C*). The loss of efficiency of a turbine nozzle operating under either the former or the latter condition is easy to understand. Over-expansion has been found to cause the greater losses, for the steam not only loses velocity because of the shock wave at the nozzle outlet, but it also acquires an unsuitable direction of flow.

When the nozzle angle is set at 2 deg and the back pressure is reduced to about 7 lb per sq in. abs, the jet expands beyond the nozzle to fill the entire channel. If the entering steam is saturated or wet, condensation will begin in the diverging portion of the nozzle, as in Fig. 5, *A*. If the entering steam is superheated there will be no condensation until the steam has left the nozzle, as in Fig. 5, *B*. Several inches beyond the end of the nozzle a severe recompression takes place, and water drops which enter with the steam frequently reveal interesting eddies at this point. There is apparently a double vortex here, a trace of which can be seen in (*A*) and (*B*) of Fig. 5. The water droplets revolve quite slowly, the same motion appearing both on the bottom of the channel and on the lower surface of the glass nozzle top.

The light scattered from the stream under these conditions is at first blue, and then it shades into orange. The explanation for this change may be that the blue light is scattered out almost completely in the first inch, leaving only the longer wavelengths to be scattered in the rest of the nozzle. The light from the arc on the low-pressure end must pass through about 10 in. of steam before it reaches the portion of the nozzle which is visible, and the moisture in this steam quite effectively scatters out the blue.

If the nozzle angle is reduced to 0 deg and saturated steam is passed through the apparatus, a preliminary condensation takes place in the parallel section. This condensation begins at about the 2 per cent moisture condition on the Mollier Diagram, and it apparently results in larger droplets than the condensation which occurs at the Wilson Line. Also, the droplets appear to grow as they pass through the nozzle, for the scattered light is at first blue and then it varies through the entire spectrum, passing in turn through green, yellow and red. This light has a peculiarly iridescent character, and it is only slightly polarized. The colors vary with the angle of observation. All of these facts indicate that the particles which are scattering the light are of the same order of magnitude as the wavelength of the light which they scatter. This matter of the growth of the droplets may be of considerable importance in steam turbine design, for the droplets which cause blade erosion must be fairly large. The factors which control the size of the drops are still being studied.

The polarization of the blue light scattered from the droplets which form at the Wilson Line gives rise to an interesting application of photoelasticity. If the light is observed through a Nicol prism or a Polaroid disk

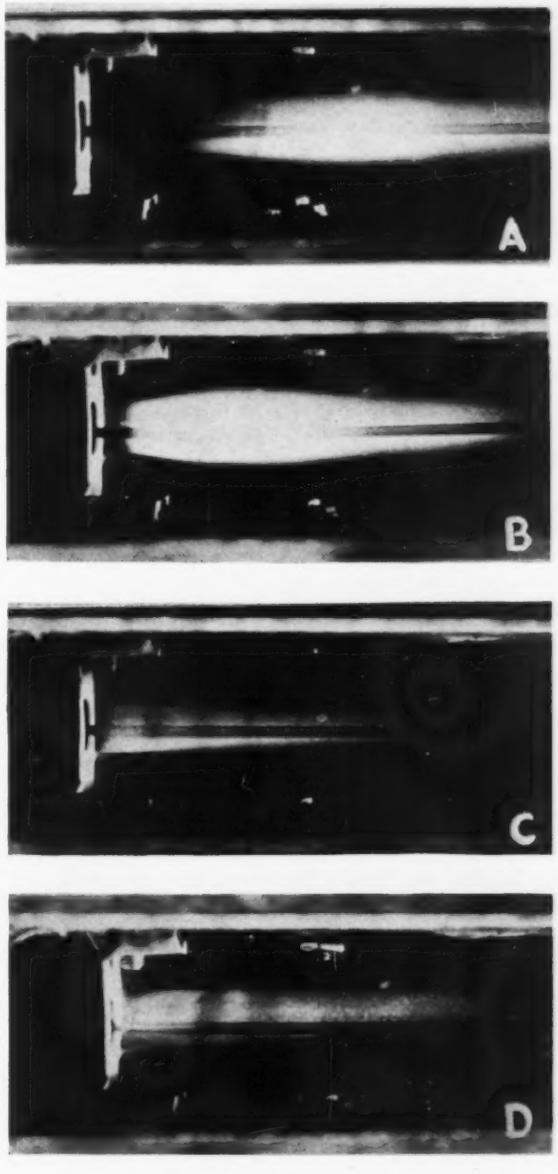


Fig. 6—Flow through a rounded nozzle

Initial conditions 60 lb per sq in. abs, 307 F.
(*A*) Back pressure 35 lb abs.
(*B*) Back pressure 30 lb abs.
(*C*) Back pressure 29 lb abs, standing waves formed.
(*D*) Back pressure 16 lb abs.

patches of blue, green, yellow and red will be seen. These colors are due to the stresses which the glass contains, and they are visible because the droplets act as the polarizer in a photoelastic setup. If a strain-free glass, such as Pyrex, is used as the nozzle top, the colors are not present.

In 1936 the writer and H. P. Culp studied the flow of steam through simple convergent nozzles and sharp edged orifices with back pressures below the critical ratio. Fig. 6 shows a series of photographs taken with a constant initial pressure of 60 lb per sq in. abs, saturated. The illumination for these pictures was from the low-pressure end only, the search tube being mounted in the high-pressure end. When the back pressure was set at 35 lb abs, a hazy whitish cloud appeared some distance beyond the nozzle outlet (*A*). When the back pressure was reduced to 30 lb abs, the outline of the jet became quite distinct, (*B*). By reducing the back pressure to 29 lb abs, a series of standing waves was set up (*C*). This is a characteristic of the flow from a rounded nozzle when the velocity exceeds that of sound. By reducing the back pressure to 16 lb abs, (*D*), the stream was caused to take on a very turbulent appearance, looking almost as if it were exploding out of the nozzle.

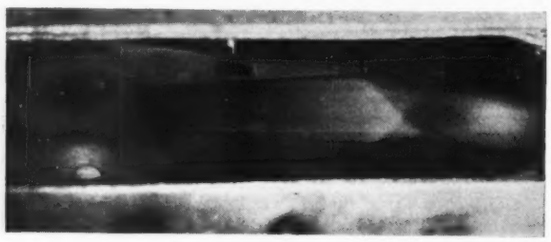


Fig. 7—Flow through over-expanding nozzle, showing Mach wave at exit

A standing wave formation of considerable interest is visible when the nozzle angle is adjusted so that over-expansion is taking place, but not to such an extent that the jet breaks away from the nozzle. Under such conditions an X-shaped Mach wave appears to originate at the tips of the nozzle blocks, extending downstream. This *X* is lighter than the surrounding steam, and it is probably caused by intersecting rarefaction waves which originate at the nozzle tips. Usually a dark spot appears beyond the vertex of the *X*, as is shown in Fig. 7. The angle between the sides of the *X* depends upon the ratio of the actual to the sound velocity and it can be changed by varying either the nozzle angle or the back pressure.

The method of observation which has been described above is limited to steam flowing at high velocities, for the moisture particles which render the stream visible form only after expansion to a pressure ratio of 0.5 or less. It is thought that valuable qualitative results can be obtained with problems concerning the flow of steam in De Laval nozzles such as are used in ejectors, steam jet refrigeration equipment and certain stages in steam turbines. The detection of even slight traces of moisture in flowing steam is also possible, and the action of separators can be studied directly.

Coal Research at Carnegie

A sum of approximately $350,000 has been subscribed for the support of the Coal Research Laboratory at the Carnegie Institute of Technology thus assuring the continuance of this internationally known research organization for four more years, according to a committee, appointed by the Carnegie Board of Trustees and headed by Dr. Thomas S. Baker, president emeritus.

In 1930 when the laboratory was founded sufficient funds for a six-year research program on bituminous coal were given by the Buhl Foundation, the Carnegie Institute of Technology and six large industrial firms, namely, the U. S. Steel Corporation, the General Electric Company, the Koppers Company, the New York Edison Company, the Standard Oil Company of New Jersey and the Westinghouse Electric and Manufacturing Company.

Through the efforts of the committee, a large number of companies have become sufficiently interested in the research work of the laboratory to promise financial aid to the enterprise. Whereas the original grant was secured from a small number of companies, the Buhl Foundation and the Carnegie Institute of Technology, the gifts secured by the present committee have been made by a more diversified group of interests, particularly coal mine owners and railroads.

A. W. Kraft, formerly secretary-treasurer of the United Illuminating Company, New Haven, Conn., has been elected president of that company, succeeding James English, its founder and president for more than fifty years.

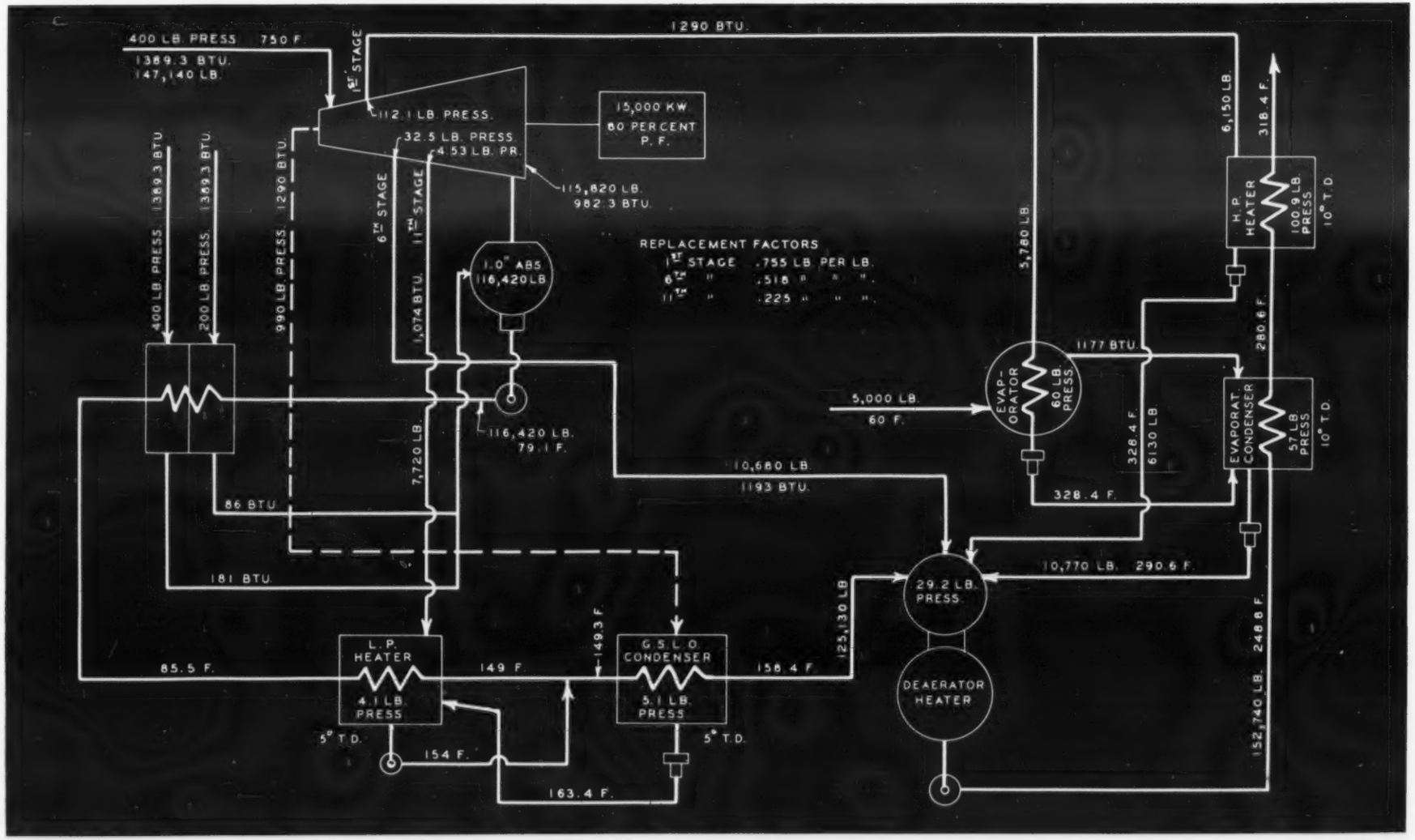
E. B. Severs has returned to active service in the organization of United Engineers & Constructors Inc., Philadelphia, and is again a member of their engineering staff, in the power engineering division.

Edgar S. Daugherty has been appointed head of the heater division of the water conditioning and purification department of the Cochrane Corporation, Philadelphia. Mr. Daugherty has been with this company since 1923, which he joined after three years at Cornell University as instructor and graduate student, following graduation from Johns Hopkins University.

J. P. H. de Windt, manager of the boiler and machinery department of the National Bureau of Casualty and Surety Underwriters, was honored by a testimonial dinner on May 3 at the Hotel McAlpin, New York, in acknowledgment of his completion of fifteen years of extremely successful work. About sixty were present including executives of major insurance companies, chief inspectors, engineers and members of the Boiler Code Committee. The dinner was presided over by D. F. Reese, vice president of The Hartford Steam Boiler Inspection and Insurance Company.

CENTRAL STATION FLOW DIAGRAMS

In the January 1937 issue a number of flow diagrams were reproduced, including high-pressure extensions now under construction. It is planned to run additional flow diagrams from time to time, thus enabling those interested to accumulate a reference file of the more prominent stations. At the suggestion of readers, the present diagrams are printed so that each is on a separate sheet to facilitate filing. This arrangement will be followed with subsequent diagrams. Descriptions of some of these stations have already been published, hence only brief explanatory captions are here given.

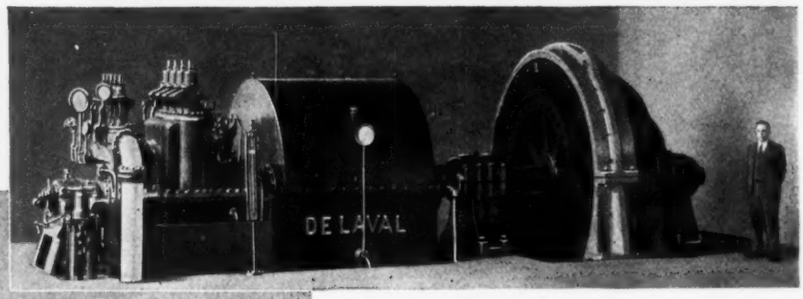


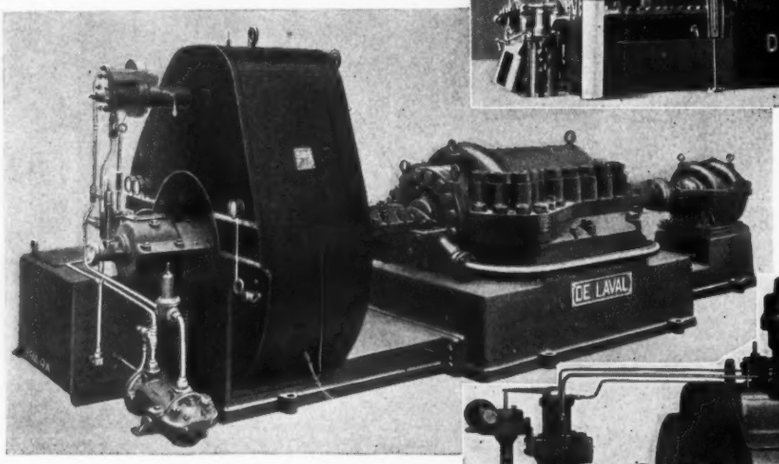
Semi-Outdoor Station of Utah Power & Light Company, near Provo, Utah

The first section of this station went into service last summer with one 200,000-lb per hr stoker-fired boiler supplying steam at 400 lb, 750 F, to a 15,000-kw turbine-generator. A second unit is now under construction.

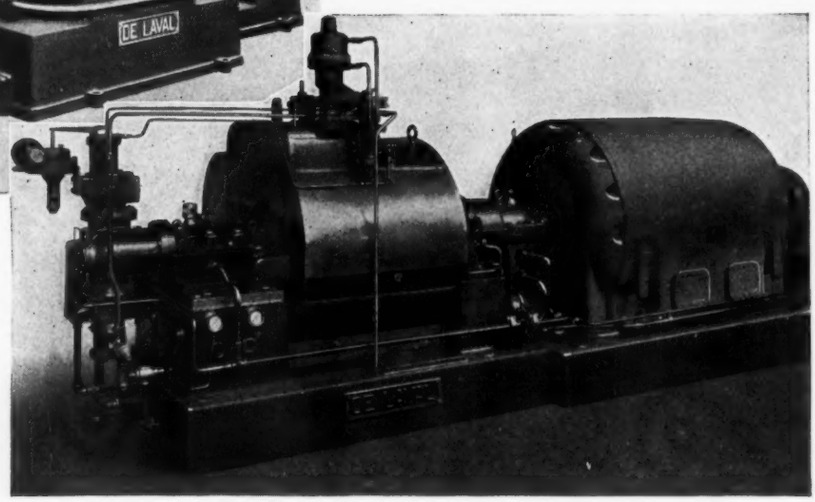
Energy on the Bus Bar
AT LOWEST TOTAL COST

● *Below—Turbine receiving steam at 600 lb. gage and 850° F., and driving high pressure boiler feed pump; 647 gal. per min. against 880 lb. per sq. in.*





● *Above — Extraction turbine driving 2500 kw. D. C. generator through double helical speed reducing gear.*



● *At right—Six-stage De Laval turbine to develop 1000 kw. from steam received at 425 lb. gage and 600° F. and delivered to process at 95 lb. gage.*

DE LAVAL STEAM TURBINES

designed to take advantage of recent metallurgical discoveries and with provision for trapping and eliminating moisture, are operated in condensing, also in back pressure and extraction service, with steam at high pressures and temperatures up to 850° F., and with the greatest reliability and efficiency. The fewer pounds of steam required per kilowatt-hour results in a reduction in cost of boiler room and condenser equipment as well as in fuel consumption, so that a great saving in total cost of power is realized, amounting in the case of superposed plants to as much as one-half the previous cost with steam at conventional pressures.

Where still higher initial pressures and temperatures are desirable, as in some process plants, the

DE LAVAL COMPOUND TURBINE

offers the advantage of confining the high temperatures and pressures to the high pressure element.

Turbines designed for modern steam conditions are available for the operation of auxiliaries or for direct or geared connection to machinery, as well as for driving A. C. or D. C. generators.

Turbine data required in the study of your power problems will be supplied upon request.

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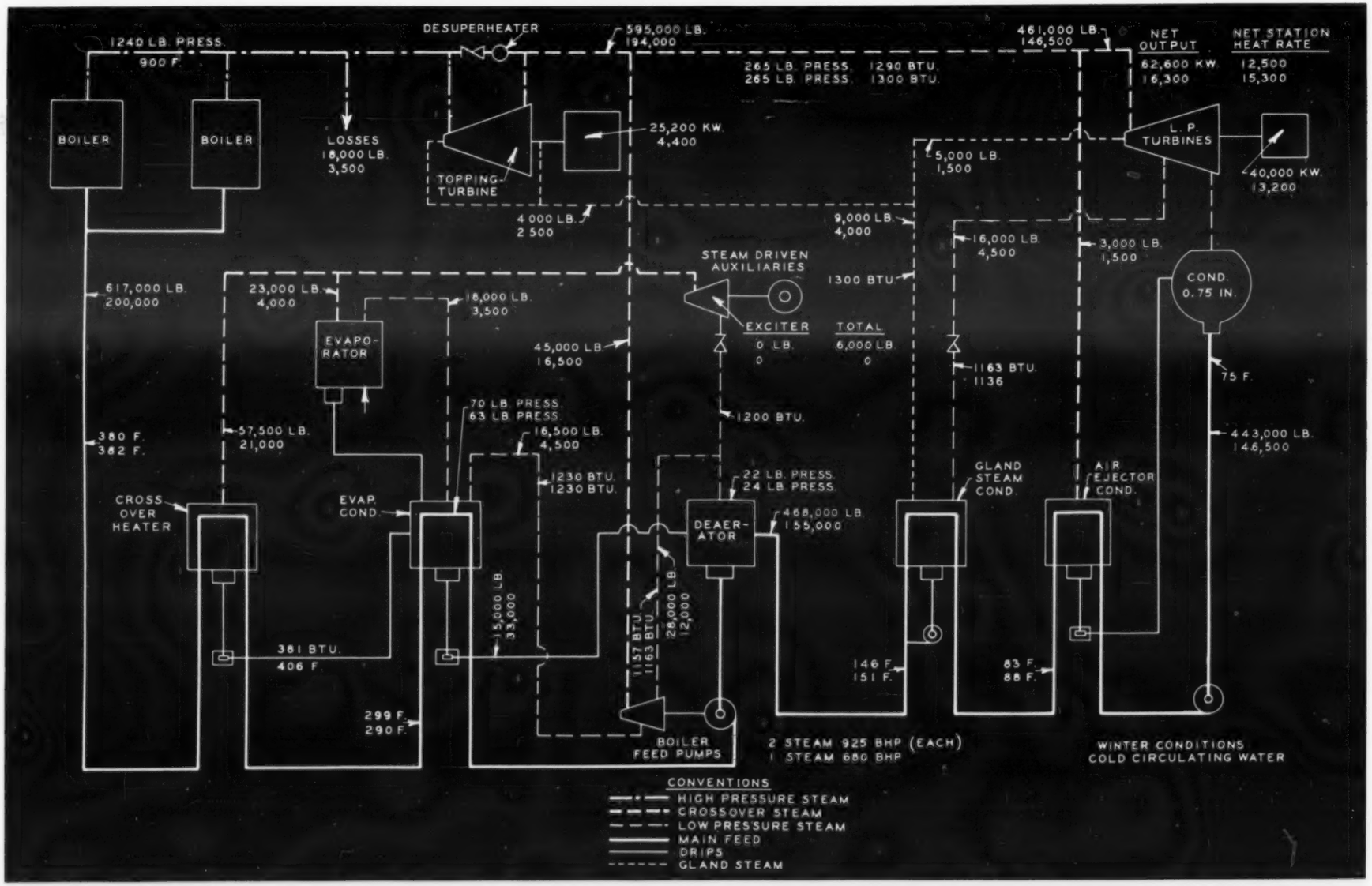
MANUFACTURERS OF STEAM TURBINES, PUMPS—CENTRIFUGAL, PROPELLER, ROTARY DISPLACEMENT; CENTRIFUGAL BLOWERS AND COMPRESSORS; WORM GEARS; HELICAL GEARS; HYDRAULIC TURBINES AND FLEXIBLE COUPLINGS • • • SOLE LICENSEE OF THE BAUER-WACH EXHAUST TURBINE SYSTEM



Rivesville Station of West Penn Power Company

The high-pressure extension to this station consists of two 315,000-lb per hr pulverized-coal-fired boilers supplying steam at 1240 lb pressure, 900 F, to a 25,200-kw high-pressure turbine exhausting to the existing low-pressure units in the station.

The sun never sets on the far-flung activities of Hagan Corporation, its subsidiaries and associates. This contact with the world at large presents many interesting engineering and chemical problems, many of which are described and related in our publication DUAL SERVICE NEWS, published quarterly for engineers, chemists and executives.

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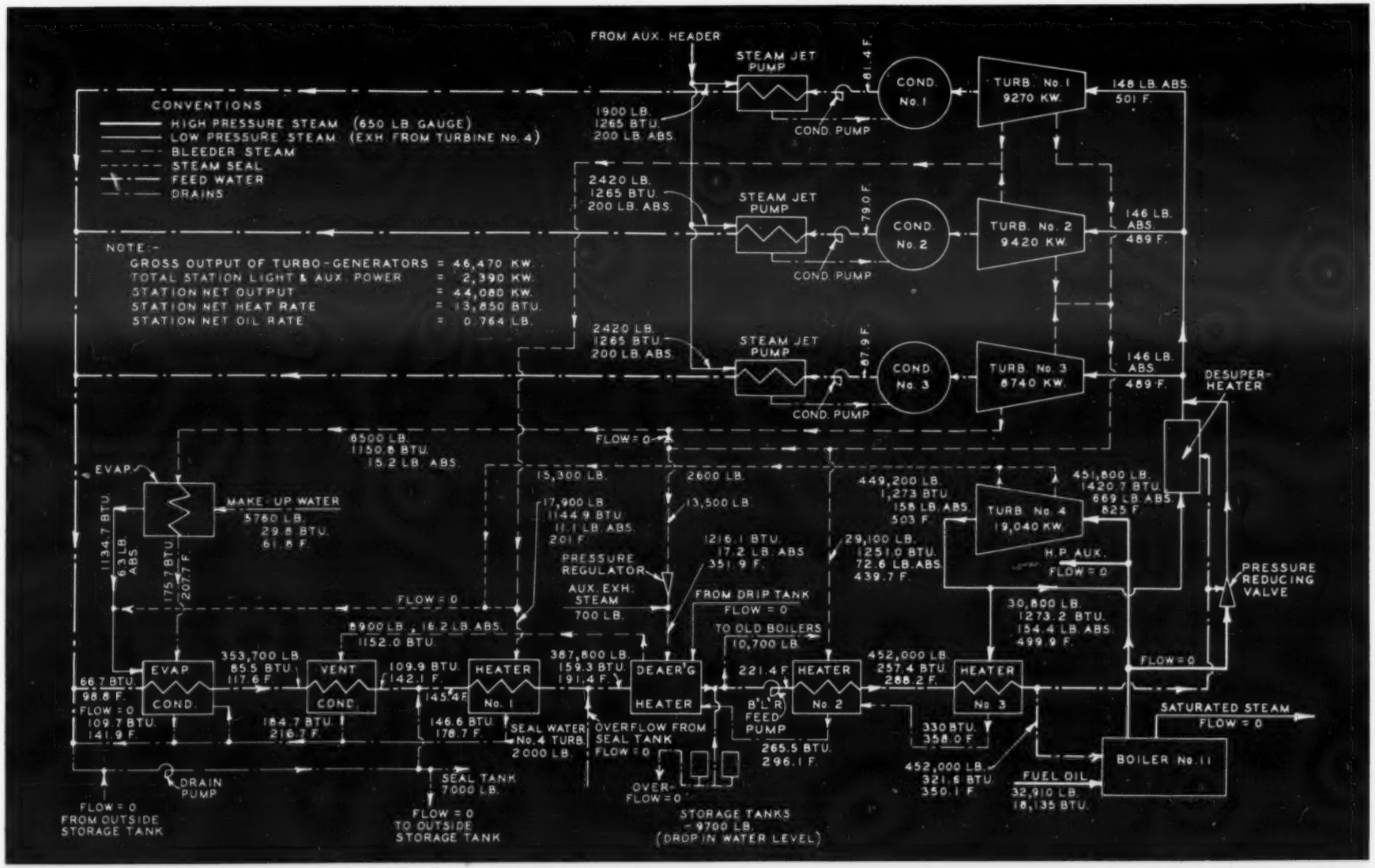
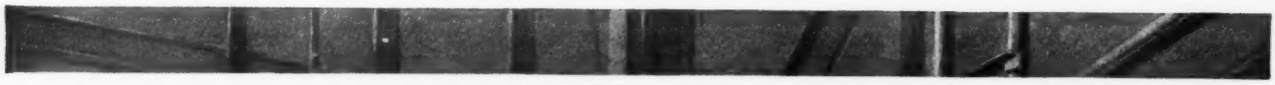
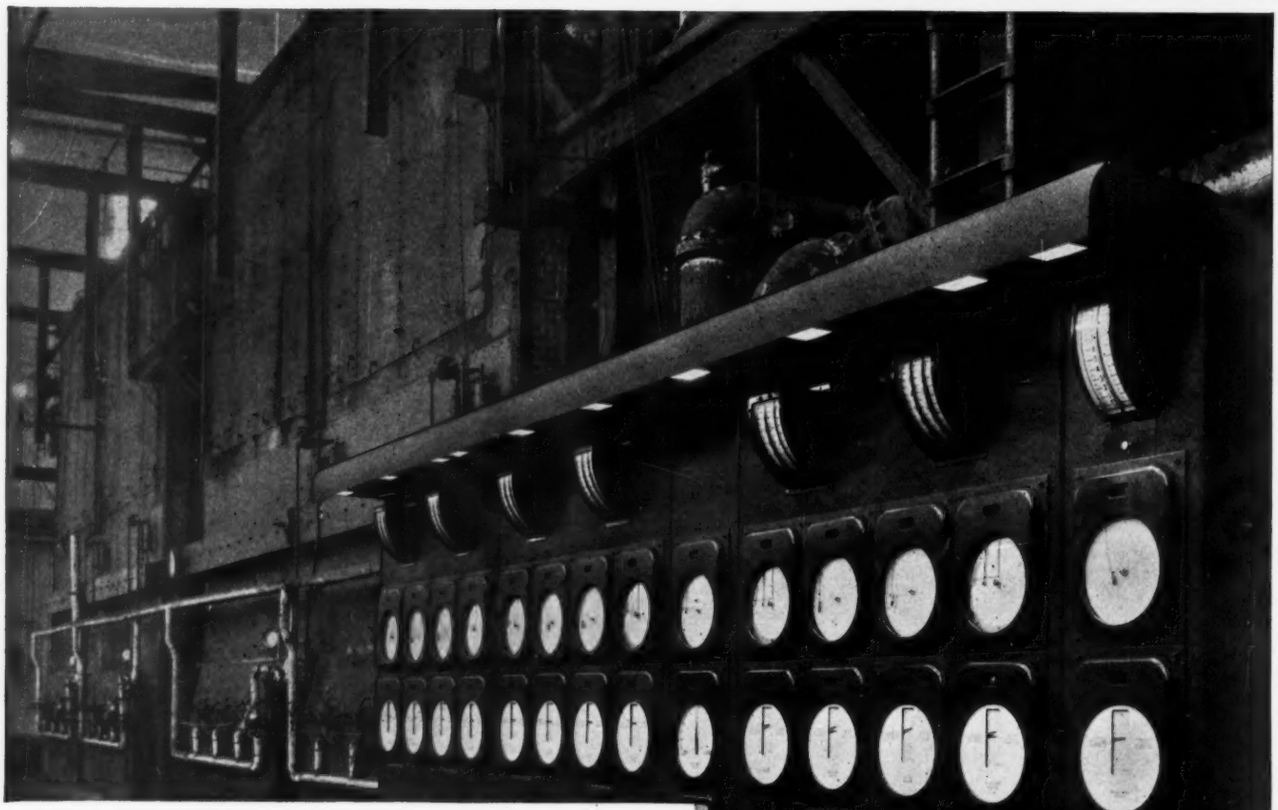

FROM AUX. HEADER
STEAM JET PUMP
COND. No. 1
TURB. No. 1 9270 KW.
148 LB. ABS. 501 F.
CONVENTIONS
HIGH PRESSURE STEAM (650 LB GAUGE)
LOW PRESSURE STEAM (EXH. FROM TURBINE No. 4)
BLEEDER STEAM
STEAM SEAL
FEED WATER
DRAINS
1900 LB. 1265 BTU. 200 LB. ABS.
COND. PUMP
2420 LB. 1265 BTU. 200 LB. ABS.
COND. No. 2
TURB. No. 2 9420 KW.
146 LB. ABS. 489 F.
NOTE:-
GROSS OUTPUT OF TURBO-GENERATORS = 46,470 KW.
TOTAL STATION LIGHT & AUX. POWER = 2,390 KW.
STATION NET OUTPUT = 44,080 KW.
STATION NET HEAT RATE = 13,850 BTU.
STATION NET OIL RATE = 0.764 LB.
COND. No. 3
TURB. No. 3 8740 KW.
DESUPER-HEATER
6500 LB. 1150.8 BTU. 15.2 LB. ABS.
FLOW = 0
EVAP.
MAKE-UP WATER 5760 LB. 29.8 BTU. 61.8 F.
15,300 LB.
2600 LB.
17,900 LB. 1144.9 BTU. 11.1 LB. ABS. 201 F.
13,500 LB.
449,200 LB. 1,273 BTU. 158 LB. ABS. 503 F.
451,800 LB. 1420.7 BTU. 669 LB. ABS. 825 F.
TURB. No. 4 19,040 KW.
1216.1 BTU. 17.2 LB. ABS. 351.9 F.
29,100 LB. 1251.0 BTU. 72.6 LB. ABS. 439.7 F.
H.P. AUX. FLOW = 0
PRESSURE REGULATOR
AUX. EXH. STEAM 700 LB.
FROM DRIP TANK FLOW = 0
PRESSURE REDUCING VALVE
30,800 LB. 1273.2 BTU. 154.4 LB. ABS. 499.9 F.
8900 LB., 16.2 LB. ABS. 1152.0 BTU.
TO OLD BOILERS 10,700 LB.
353,700 LB. 85.5 BTU. 117.6 F.
387,800 LB. 159.3 BTU. 191.4 F.
452,000 LB. 257.4 BTU. 288.2 F.
EVAP COND.
VENT COND.
HEATER No. 1
DEAER'G HEATER
HEATER No. 2
HEATER No. 3
221.4 F.
FLOW = 0
SATURATED STEAM FLOW = 0
B'L'R FEED PUMP
265.5 BTU. 296.1 F.
330 BTU. 358.0 F
452,000 LB. 321.6 BTU. 350.1 F
BOILER No. 11
FUEL OIL 32,910 LB. 18,135 BTU.
SEAL WATER No. 4 TURB. 2000 LB.
OVERFLOW FROM SEAL TANK FLOW = 0
SEAL TANK 7000 LB.
DRAIN PUMP
FLOW = 0 FROM OUTSIDE STORAGE TANK
FLOW = 0 TO OUTSIDE STORAGE TANK
OVER-FLOW = 0
STORAGE TANKS ~9700 LB. (DROP IN WATER LEVEL)

Burlington, N. J., Station of the Public Service Electric and Gas Company

Boiler No. 11, rated at 525,000 lb per hr, 700 lb pressure and 860 F steam temperature, supplies an 18,000-kw turbine-generator which exhausts to the low-pressure units. The data given in this flow diagram represent conditions for a station load of 46,470 kw which is close to the most efficient, although not maximum, loading of the station.



Complete INSTRUMENTATION *and Automatic* COMBUSTION CONTROL



CENTRALIZED INSTRUMENT AND CONTROL PANEL

For seven oil-fired boilers in the power plant of the Bigelow Sanford Carpet Co., Inc., Thompsonville, Conn.

ON this one well lighted and unified panel are assembled the Carrick Control units; Cochrane steam flow, pressure, and temperature instruments; Hays combustion meters; and other necessary recording and indicating instruments. The Carrick Combustion control units are housed in standard instrument cases, flush mounted to harmonize with the instruments. Selector switches and push button stations on the panel enable the operator at his central control station to make manual adjustments of dampers, air supply, fuel feed, etc., while observing the indicating and recording instruments. We will gladly send full information on complete instrumentation and control. ***Write for it!***

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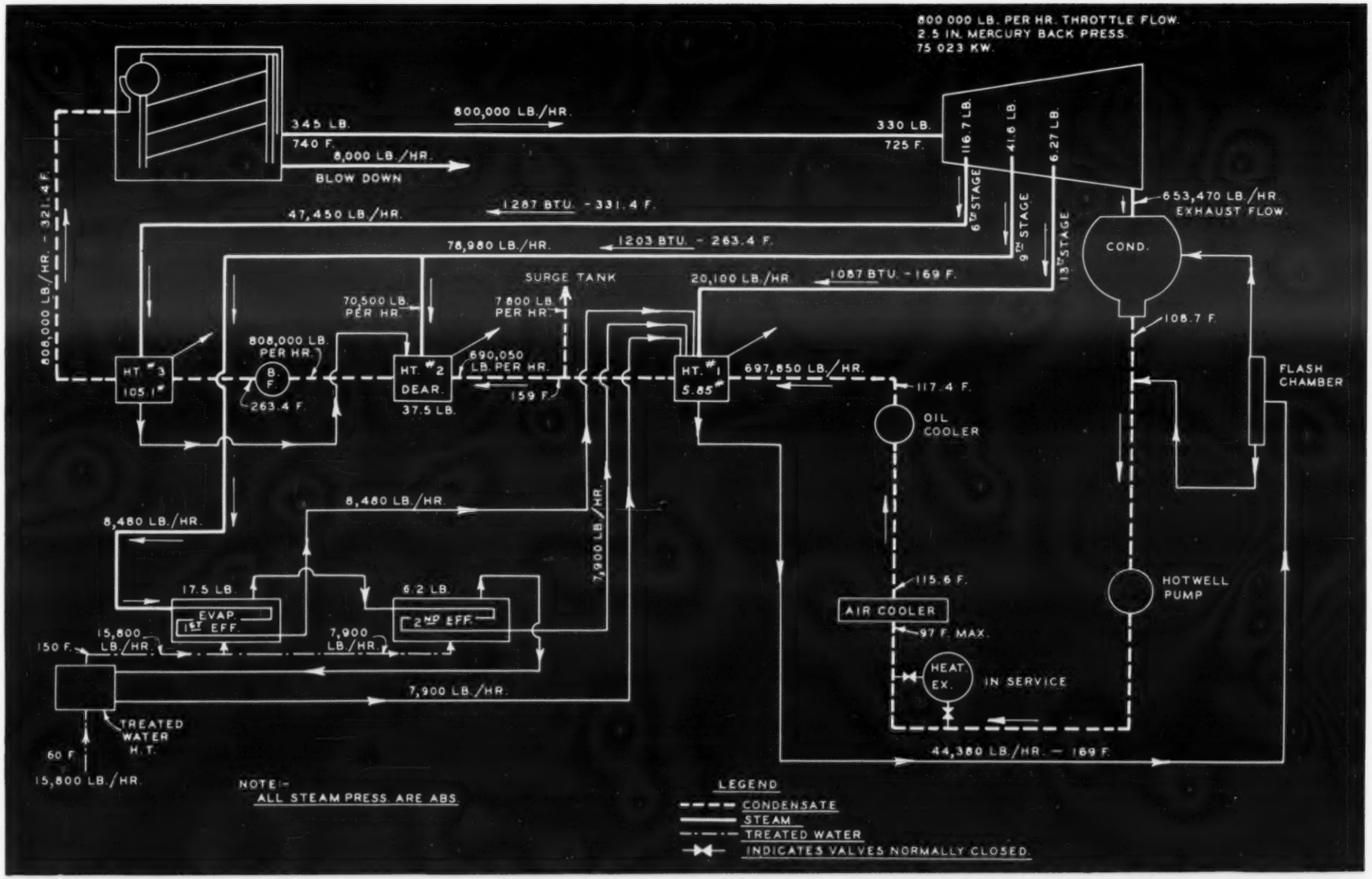
MICHIGAN CITY, INDIANA, U.S.A.



Cahokia Station of Union Electric Light and Power Company, St. Louis

Flow diagram for new 75,000-kw single-cylinder condensing unit supplied with steam at 345 lb, 740 F, by five 190,000-lb per hr boilers. This addition brings the total capacity of the station up to 235,000 kw and the calculated net heat rate of the new section is 13,920 Btu per kwhr.

Laboratory at plant of Pennsylvania Sugar Company—a Cochrane-equipped boiler plant

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CREEP and CORROSION
Discussed at International Congress

Of the seventy-six papers by engineers and metallurgists from various countries, those dealing with the mechanism of creep, engineering design for creep, creep recovery, chemical properties and stability of metals at high temperatures and the influence of temperature on corrosion, were of particular interest to power plant designers. These papers are briefly abstracted.

ON APRIL 19 to 24 a congress of the International Association for Testing Materials was held in London at which seventy-six papers were presented covering the behavior of metals, the progress of metallurgy, light metals and their alloys and workability and wear. Of special interest to the power field were the papers dealing with creep and corrosion at high temperatures.

Dr. W. H. Hatfield, of the Brown-Firth Research Laboratory, Sheffield, listed the relative creep resistances of various steels employed in power station practice, based on a survey of thirty British power stations and twenty marine installations.

Those listed in Table I include, mostly, steels operating at temperatures under 450 C (842 F), which are expected to retain, within very critical limits, their form and dimensions under service stresses for the full life of the parts. The first group in this table includes steels employed in boiler drums, the second group, steels for bolts and auxiliary equipment, and the third group, corrosion-resisting steels as employed in turbine rotors, wheels, casings, spindles, blading, etc.

Table II includes steels operating under temperatures from 550 to 1000 C (1020 to 1832 F) where, owing to the nature of the service, only relative life is expected and not the same continuance of form and dimensions. In this category fall steels for superheater supports, chain grates, links, sprockets, boiler stays, tube spacers, tube ferrules and certain furnace parts.

The "time-yield," as given in the tables, represents, in effect, the stress which, during the second and third twenty-four hours, does not produce creep in excess of the rate of one millionth inch (0.000025 mm) per inch per hour, the first twenty-four hours being given up to the development of the initial deformation which must not exceed 0.5 per cent of the gage length.

Mechanism of Creep

Dr. C. L. Clark and Dr. A. E. White, of the University of Michigan, discussed certain theories that have been developed concerning the mechanism of creep. These theories are based on the following two conceptions: First, it is assumed that at all temperatures the creep or deformation resulting from the application of stress over a given period is a running balance between the yielding of the material and the strain-hardening caused by such yielding. At certain temperatures the strain-hardening characteristics will predominate and thus creep will stop unless the stress is sufficiently great; at others, the rate of recrystallization will be the deciding factor and creep will continue even under the lowest of stresses. If this be true, then there must exist for each material a critical temperature, or temperature range, which may be defined as the lowest temperature of recrystallization.

The second conception assumes that the mechanism of deformation changes with increasing temperature. Confining the discussion to prolonged testing periods, at certain temperatures the deformation is believed to occur largely by slippage along the crystallographic planes, and since these crystals are elastic bodies the metal exhibits elastic properties. At the more elevated temperatures the deformation is believed to occur through the movement of the crystals themselves, that is, within the material surrounding the grains. Regardless of the nature of this intergranular material and whether it is amorphous or consists of severly strained crystals, it is generally agreed that it is not elastic. Accordingly, metals at these more elevated temperatures exhibit plastic rather than elastic properties. This conception also requires the existence of a critical temperature, or temperature range, and, since in those cases in which the deformation is within the crystals the fracture is transcrystalline and for those cases in which the deformation occurs in the grain boundaries the fracture is intercrystalline, this temperature is, by definition, the equicohesive temperature.

On the basis of these two theories the influence of the various factors on the creep resistance can be readily explained as follows:

1. CHEMICAL COMPOSITION—Elements which form carbides (Cr, W, Mo, V, Ti) and thus interfere with slippage along the crystallographic planes, as well as with the movement of the individual grains, increase the creep resistance over the complete temperature range. On the other hand, those elements which are largely soluble in the ferrite (Ni, Mn, Si, Al, Cu) and thus strengthen the crystals, increase the creep resistance only at those temperatures below the equicohesive temperature or lowest temperature of recrystallization.

2. GRAIN SIZE—A fine grain size, based on either the actual or the inherent grain structure, possesses the maximum creep resistance at temperatures below the equicohesive temperature, whereas at temperatures above it a coarse grain structure is superior.

3. HEAT TREATMENT—The heat treatment producing the suitable grain size imparts the maximum creep resistance.

Creep Recovery

H. J. Tapsell, of the National Physical Laboratory, discussed creep recovery. He pointed out that it had been observed, when test specimens which had been creeping under stress at a high temperature were unloaded at that temperature, the immediate elastic contraction was followed by continuous contraction with time, or creep recovery. This contraction, which took place fairly rapidly at first, was observed to continue in certain cases for thousands of hours after the release of stress. However, if only a fraction of the stress was removed, recovery took place after a time but gave way to renewed extension as a result of the continuous application of the reduced stress. When the initial stress is such that the creep strain is small, the creep recovery may become a relatively large fraction of both the creep strain and the initial elastic strain.

The author pointed out, however, that creep recovery is probably seldom of much significance in practice, since maintenance of temperature after release of stress is needed for its development, and further, when the original stress is again applied, creep occurs much more rapidly than just before the stress was released, so that contraction due to creep recovery is soon cancelled. It may possibly have some practical significance for soft metals which creep at normal air temperatures.

Effects of Temperature

C. E. MacQuigg, Director of Research of the Union Carbide and Carbon Research Laboratories, New York, discussed the effect of temperature on the properties of steels. As to the effect of various elements on steels he listed the following:

1. For low temperatures, nickel, chromium, copper, vanadium and zirconium have been favorably mentioned.
2. For resistance to deformation alone and in the absence of marked attack by surrounding media, carbon steels containing molybdenum are used. For greater chemical inertness, from 2 to 9 per cent chromium is used as the principal alloying element, with its resistance to creep reinforced chiefly by molybdenum and/or tungsten.
3. For surface stability at high temperatures, 20 per cent or more chromium is used with or without nickel, although as little as 15 per cent chromium may be specified, provided considerable nickel is present. Great surface stability may be imparted by titanium or aluminium, in which case the chromium may be lower than in the preceding categories.
4. Stabilization against susceptibility to embrittlement is imparted by molybdenum, titanium and particularly columbium.

Engineering Design for Creep

R. W. Bailey, of the Research Department, Metropolitan-Vickers Electrical Co., Ltd., pointed out that heretofore insufficient attention has been paid to the influence upon the material of prolonged thermal action and stress in service. Appreciable weakening of steel may occur in time, and evidence shows that probably all low-alloy, high creep-resistant steels fail under creep

TABLE I.—*Steels used in the Temperature Range* 400–550° C.

Reference No.	Analysis of Steel. C.	Si.	Mn.	Ni.	Cr.	Mo.	Form and Condition.	Ultimate Tensile Stress at 15° C. Tons per sq. in.	Kg. per sq. mm.	Time Yield. 400° C. Tons per sq. in.	Kg. per sq. mm.	500° C. Tons per sq. in.	Kg. per sq. mm.	550° C. Tons per sq. in.	Kg. per sq. mm.	Safe Stress. 400° C. Tons per sq. in.	Kg. per sq. mm.	500° C. Tons per sq. in.	Kg. per sq. mm.	550° C. Tons per sq. in.	Kg. per sq. mm.
Forgings Steels.																					
A.	0·24	0·16	0·55	0·11	0·05	...	Annealed, 670° C.	28·4	44·7	7·0	10·9	3·3	5·2	1·7	2·7	4·7	7·4	2·2	3·5	1·1	1·6
B.	0·28	0·18	0·38	0·15	...	...	Normalised, 865° C.	34·5	54·3	7·7	12·0	3·8	6 0	1·7	2·7	5·1	8·0	2·5	3·9	1·1	1·6
C.	0·24	0·20	0·55	3·30	...	...	Normalised, 850° C.	40·85	64·3	10·2	16·1	4·7	7·4	2·1	3·3	6·8	10·6	3·1	4·9	1·4	2·2
D.	0·07	1·32	0·54	0·17	6·24	0·56	Oil-hardened, 950° C. Tempered, 700° C.	45·5	71·6	13·0	20·5	5·2	8·2	2·8	4·4	8·6	13·5	3·5	5·5	1·9	3·0
E.	0·31	0·32	1·10	0·55	...	0·28	Oil-hardened, 870° C. Tempered, 650° C.	52·25	81·3	16·0	25·2	8·0	12·6	3·5	5·5	10·6	16·7	5·3	8·3	2·3	3·6
F.	0 24	0·26	0·47	0·22	0·07	0·64	Annealed, 650° C.	36·2	57·0	16·5	26·0	8·75	13·8	3·5	5·5	11·0	17·3	5·8	9·1	2·3	3·6
G.	0·28	0·13	0·51	2·76	0·67	0·61	Air-cooled, 875° C. Tempered, 600° C.	61·0	96·1	22·5	35·4	10·0	15·7	4·0	6·3	15·0	23·6	6·6	10·4	2·7	4·2
Steels for Bolts and Auxiliary Equipment.																					
H.	0·32	0·25	0·57	3·01	1·06	0·55	Oil-hardened, 850° C. Tempered, 620° C.	69·8	109·9	22·0	34·6	9·5	15·0	3·9	6·1	14·6	23·0	6·3	9·9	2·6	4·1
I.	0·43	0·20	0·60	0·21	1·30	0·85	Oil-hardened, 850° C. Tempered, 675° C.	64·3	101·3	21·5	33·9	6·6	10·4	3·8	6·0	14·3	22·5	4·4	6·9	2·5	3·9
Corrosion-Resisting Steels.																					
J.	0·11	0·22	0·32	2·64	18·14	...	Oil-hardened, 950° C. Tempered, 650° C.	54·9	86·5	16·0	25·2	3·5	5·5	1·6	2·5	10·7	16·8	2·3	3·6	1·1	1·6
K.	0·15	0·81	0·36	0·19	14·66	...	Air-cooled, 1000° C. Tempered, 700° C.	45·1	71·0	14·75	23·2	6·0	9·4	2·5	3·9	9·8	15·4	4·0	6·3	1·7	2·7
L.	0·29	0·30	0·28	0·35	13·04	...	Oil-hardened, 975° C. Tempered, 750° C.	48·0	75·6	14·5	22·8	5·9	9·3	2·5	3·9	9·7	15·3	3·9	6·1	1·7	2·7
						Ti Al															
M.	0·11	0·72	0·35	8·46	18·70	0·86 1·52	Air-cooled, 1050° C.	50·1	78·9	29·0	45·7	19·0	29·9	9·5	15·0	19·3	30·4	12·6	19·8	6·3	9·9

TABLE II.—*Steels used in the Temperature Range* 550–1000° C.

Reference No.	Analysis of Steel. C.	Si.	Mn.	Ni.	Cr.	W	Ti.	Al.	Ultimate Tensile Stress. 15° C. Tons per sq. in.	Kg. per sq. mm.	600° C. Tons per sq. in.	Kg. per sq. mm.	700° C. Tons per sq. in.	Kg. per sq. mm.	800° C. Tons per sq. in.	Kg. per sq. mm.	900° C. Tons per sq. in.	Kg. per sq. mm.	1000° C. Tons per sq. in.	Kg. per sq. mm.	Condition.
N	0·28	1·60	0·55	11·5	23·0	3·0	...	...	51·0	81·6	38·5	60·6	27·5	43·3	19·0	29·9	12·6	19·8	6·1	9·6	Air-cooled, 1050° C.
O	0·40	0·97	0·41	10·31	13·65	3·53	...	...	63·0	94·5	34·1	53·7	28·2	44·4	17·2	26·1	12·0	18·9	6·0	9·4	Air-cooled, 950° C.
P	0·25	0·31	1·22	35·45	13·52	...	...	...	45·4	71·5	29·5	46·5	22·3	35·1	14·4	22·7	...	...	...	...	Air-cooled, 850° C.
Q	0·15	0·68	0·60	19·95	26·37	...	...	...	42·0	66·1	27·6	43·4	22·6	35·6	12·6	19·8	7·5	11·8	4·4	6·9	Air-cooled, 1050° C.
M	0·11	0·72	0·35	8·46	18·70	...	0·86	1·52	50·1	78·9	28·1	44·2	17·9	28·2	9·6	15·1	5·4	8·5	3·7	5·8	Air-cooled, 1050° C.
R	0·13	0·50	0·33	8·22	18·65	0·63	0·61	...	42·6	67·1	24·7	38·9	17·5	27·6	13·1	20·6	7·8	12·4	4·6	7·2	Air-cooled, 1050° C.
S	0·22	0·69	0·56	0·26	30·41	...	...	...	34·1	53·7	15·8	24·9	9·7	15·3	4·4	6·9	2·0	3·1	1·0	1·6	Oil-quenched, 1050° C. Tempered, 700 C.

conditions by intercrystalline cracking with comparatively low ductility. Both effects must be allowed for; the first by ascertaining and allowing for the weakening effect, and the second by limiting the permissible creep so as to be well within the minimum creep at fracture. For this reason, it is recommended that the total creep not exceed 0.005 strain for high creep-resistant steels containing molybdenum and for weld deposits of these steels, which under creep may have no more than 1 or 2 per cent extension at fracture.

Weakening by prolonged thermal action makes the use of short-time tests by themselves unreliable for determining working stresses and the real capabilities of different steels.

Apparently, the addition of 1 per cent chromium to a 0.5 per cent molybdenum steel increases its initial resistance to creep, but it also appears to increase the rate of weakening under thermal action, with the result that below a certain temperature, the stiffening effect of the chromium will predominate over the weakening by thermal action, and the chromium-molybdenum steel may be expected to show less creep in service than the plain molybdenum steel. Above that temperature the greater weakening by thermal action of the chromium-molybdenum steel would make this steel inferior to the plain molybdenum steel.

Chemical Properties and Stability of Metals at High Temperatures

C. H. M. Jenkins, of the National Physical Laboratory, discussed this phase of the problem. A rise in temperature brings about increased mobility of the atoms, which affects the properties of the material, as disclosed by tests, and increases the surface activity toward surrounding media. This fundamental property forms the basis of the change in behavior with increase of temperature.

An increase of internal mobility facilitates both softening and recrystallization, whereas a decrease tends to produce, on deformation, a more marked occurrence of slip and work-hardening in the neighborhood of the slip planes. Flow occurs in metallic aggregates in three ways which are not necessarily independent, namely: by slip within the crystals, by grain boundary movement and by continuous recrystallization under stress.

The influence of chemical composition and the mode of manufacture of mild steels has been investigated and evidence has been obtained that the ingot conditions are traceable in the final rolled product.

Corrosion as Influenced by Increased Temperature

U. R. Evans, of the Metallurgical Laboratories, Cambridge University, in discussing the influence of high temperature on corrosion, stated that the rate of combination between metallic atoms and oxygen atoms at high temperature is very rapid; that the rate of wastage of metals exposed to hot oxidizing gases is usually only limited by the rate of penetration of oxygen inward through the oxide coat to the metal, or by the rate of diffusion of metal outward to the oxygen. The heavy metals, such as iron, occupy a smaller volume than the oxides which they yield on heating; the oxide scale produced on such metals is still in a state of lateral compression, which reduces its porosity; and in the absence of cracking, the rate of access of oxygen to the unchanged metal below becomes increasingly slow as the oxide scale thickens. Unfortunately, the tendency to crack or to peel is greater for thick scales than for thin scales. Therefore, for use at very high temperatures it is necessary to employ an alloy capable of giving an oxide scale which becomes almost impervious to oxygen, even at high temperatures, while it is still thin and adherent. Many alloys containing chromium, aluminium and silicon possess these desirable properties.

When moisture-bearing gas is cooled below the dew-point, it will deposit moisture on any metallic surface, producing a form of corrosion unknown at high temperatures. Actually, corrosion of this character may become serious when the relative humidity is still well below 100 per cent. For vigorous attack of the humid type the relative humidity of the air must, however, exceed a certain critical value. Here, therefore, a low temperature may cause more corrosion than a higher temperature. Attack occurs on economizer tubes when moisture from the flue gases, which may contain sulphuric acid or suspended sulphates, is allowed to condense on the surface, but there is little trouble if the surface is kept well above the condensation temperature, which lies higher than the dew-point owing to the hygroscopic nature of the deposit.

The rate of corrosion of immersed metal is often connected with the rate of supply of dissolved oxygen to the metallic surface. A rise in temperature will accelerate the diffusion of oxygen and favor the electrochemical reactions, but will decrease the solubility of oxygen. Thus the corrosion rate first rises with temperature and then diminishes. A fluctuating temperature, by setting up convection currents, will facilitate oxygen transfer and cause quicker attack than a constant temperature under stagnant conditions. Most types of wet corrosion would be considerably more rapid at 212 F than at some lower temperature were it not for the fact that oxygen and other stimulators of corrosion are frequently driven out of solution by heat. Therefore, corrosion in hot-water systems is much more serious when the design is such that the gas eliminated by the heating continues to circulate with the water. Where heat has to pass through the metal walls the "hot wall" effect becomes important.

If water containing dissolved air passes through a hot metal container such as a boiler or condenser tube, air will be forced out of solution and will adhere in bubbles to the metallic surface at certain points. These bubbles will prevent the water from exercising its normal cooling effect and thus the temperature may become very high. At the same time the oxygen previously dissolved in the water can still play its part in the corrosion process.

Dr. Sven Brennert, of Stockholm, discussed pitting in stainless steel. He pointed out that resistance of stainless steel to corrosion is due to a film, probably an oxide film, which is formed on the surface and has a high resistance to corrosive solutions. As soon as the film covers the whole surface the material is quite resistant (passivified). If a surface which has been passivified is exposed to a neutral solution with highly corroding properties it may be that the film is broken through at a few weak points and that local attacks arise at these points. Resistance of the steel to corrosion is thus dependent upon the resistance of the weakest points of the surface.

It is found that breaking-through of the film takes place at a certain potential. It is further well known that hot water containers should not be made of 18–8 stainless steel because they are easily destroyed by the formation of pitting. On the other hand, cold water containers are preferably made of such material.

Waterside High-Pressure Turbine Nears Completion

Some features of one of the 53,000-kw, 1200-lb, 900 F, 3600-rpm turbine-generators that will go into the superposed extension to Waterside Station. A novel feature of this unit is the incorporation of a 3500-kw feed-heating turbine which takes steam at the exhaust pressure of the high-pressure unit and both bleeds and exhausts to feedwater heaters.

ONE of the high-pressure turbines for the superposed extension to the Waterside No. 2 Station of the Consolidated Edison Company of New York, Inc., is rapidly nearing completion, as is indicated by the accompanying photograph which shows the rotor being lowered into the cylinder at the Westinghouse South Philadelphia Works.

This is a two-cylinder combination impulse-reaction unit and consists of two turbines in tandem driving a single 53,000-kw hydrogen-cooled generator at 3600 rpm. It embodies an important innovation in that the second turbine is a feed-heating unit for the high-pressure boilers. The main turbine, rated at 49,500 kw, will take steam at 1200 lb, 900 F, and exhaust into the 200-lb station header which supplies steam to the existing 35,000-kw low-pressure units in Waterside No. 1. A part of this 200-lb exhaust, however, will be used for the final stage of feedwater heating for the 1400-lb boilers.

The second, or smaller, turbine of this unit, rated at 3500 kw, takes steam at the exhaust pressure of the main turbine, namely 200 lb, bleeds at 60 lb and exhausts at 5-lb gage to a deaerating heater.

Condensate from the 35,000-kw low-pressure machines in Waterside No. 1 is first heated by exhaust from the steam-driven auxiliaries in that station to about 150 F. It then will pass to the deaerating heaters in No. 2, utilizing the 5-lb exhaust from the feed-heating turbine; thence to heaters supplied by the 60-lb extracted steam; and finally to heaters supplied by a part of the 200-lb exhaust from the main high-pressure turbine which will raise the feedwater temperature to 375 F before entering the high-pressure steam generating units. This arrangement of having a feed-heating turbine was necessary owing to the lack of bled steam for feedwater heating, the 35,000-kw, 200-lb units in Station No. 1 not being provided for extraction operation.

Fig. 2 shows the exhaust pressure control for the tandem turbine arrangement. The main inlet valves are

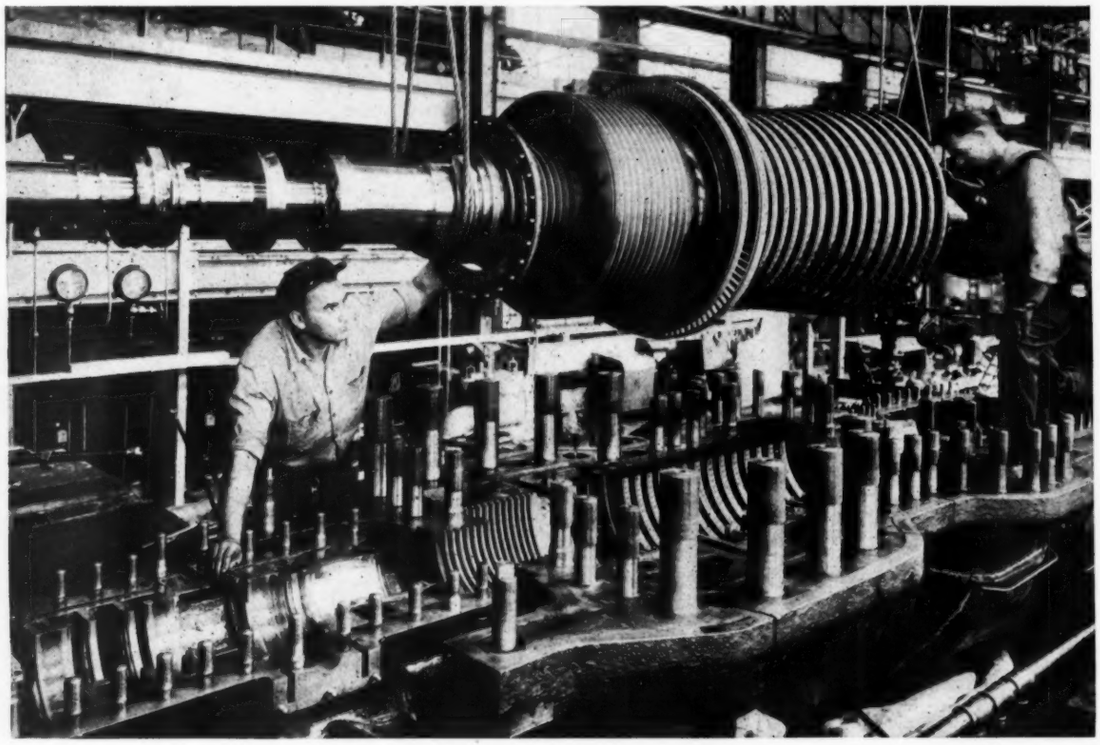

Fig. 1—Lowering the rotor into the casing

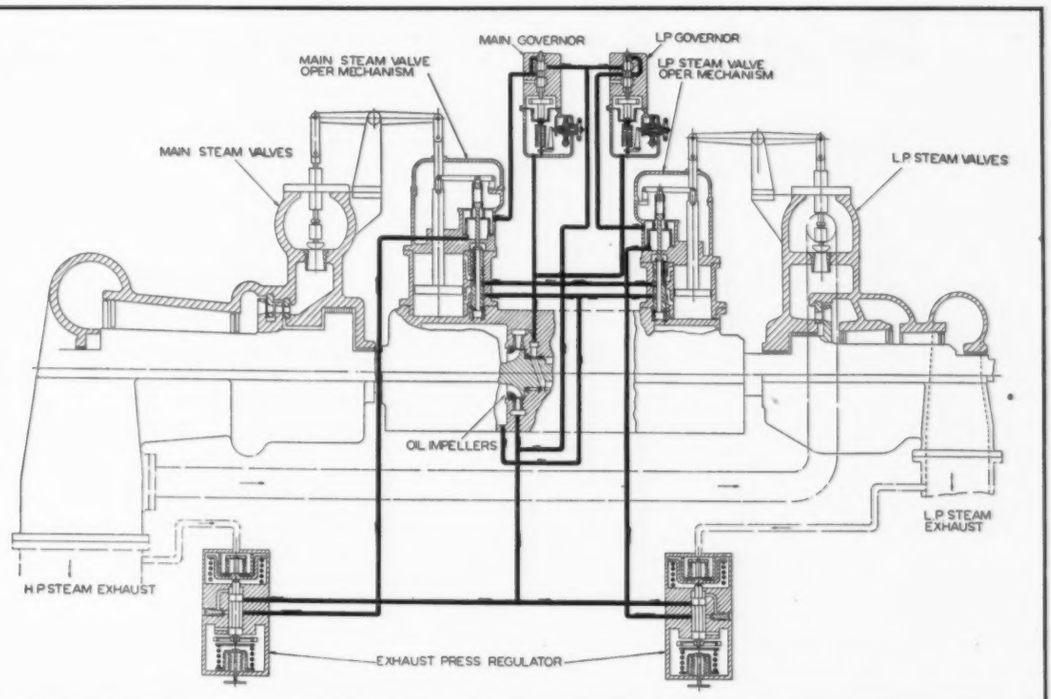

Fig. 2—Exhaust pressure control

responsive to either speed or main exhaust pressure, while the inlet valves of the feed-heating turbine are controlled by the 5-lb gage exhaust pressure. The only uncontrolled pressure will be that at the extraction point, which will be 60-lb gage at full load.

In the high-pressure section the blade path consists of a double-row impulse element followed by fourteen reaction stages exhausting at 200 lb. The impulse blades are of milled stainless steel and the reaction blades are of stainless steel fitted with welded shrouds. In the feed-heating unit the blade path consists of a single-heating row impulse element followed by twenty-three reaction stages of the radial clearance type. This blading is also of stainless steel.

Both cylinders are in two pieces, the high-pressure section being of cast carbon-molybdenum steel and that of the feed-heating section of annealed cast carbon steel. The high-pressure spindle is forged from chrome-nickel-molybdenum steel and the two sections of the unit are connected by a flexible coupling.

Dr. Robert H. Fernald

Dr. Robert H. Fernald, widely known mechanical engineer and dean of engineering at the University of Pennsylvania, died of a heart ailment on April 24. He was in his sixty-sixth year.

Following graduation from the University of Maine and graduate studies at the Massachusetts Institute of Technology, Dr. Fernald taught successively at the Case School of Applied Science, Cleveland, Washington University, St. Louis, and the University of Pennsylvania. His teaching was interspersed with consulting activities and for some years he was also associated with the U. S. Geological Survey and the Fuels Division of the U. S. Bureau of Mines.

An active member of the American Society of Mechanical Engineers since 1900, he had served successively as manager and vice president and was promoted to the grade of Fellow in 1936. He was chairman of the A.S.M.E. Power Test Codes Committee.

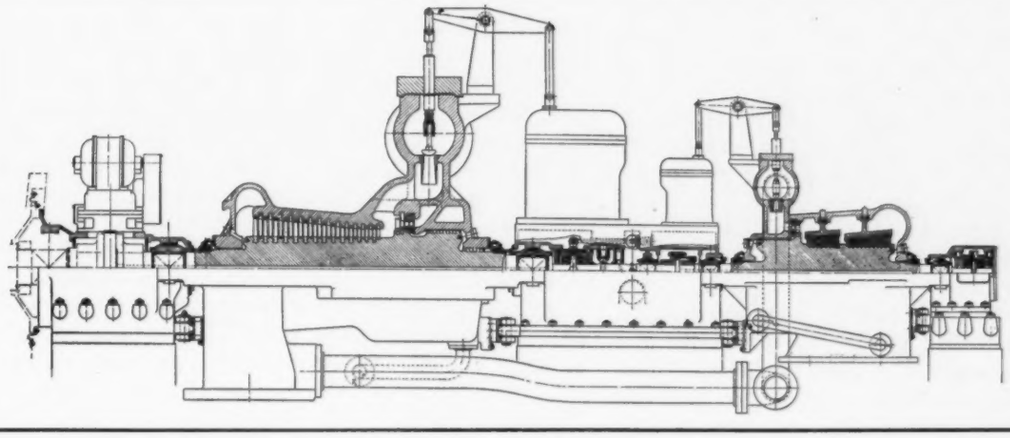

Fig. 3—Section through unit

Relation of Burning Equipment to Coal Selection*

By E. C. PAYNE

Fuel Consultation Service Dept.
Consolidation Coal Company, Inc.

The author presents a brief for closer cooperation between the plant engineers, the consulting engineer, the fuel specialist, the equipment manufacturer and the coal producer when laying out a new plant or modernizing an existing plant, to the end that the use of premium fuels may become unnecessary and that a wider latitude in coal selection, particularly with reference to the future, will be possible.

DURING the past five or six years, the average power plant has been operated at partial capacity, and because of light demands on the combustion equipment, the question of fuel application has not been a serious one. At the present time, however, this old equipment, much of which has reached a stage of obsolescence, is being called upon to meet the demands of a reviving industrial expansion that is impossible with any degree of economy.

Premium coals with special characteristics are being purchased in order to carry greater steam loads. Excessive costs and lower efficiencies are being temporarily permitted until these conditions can be rectified by the modernization of the existing plants and the construction of new units to meet anticipated needs.

The purchase of new equipment, involving a substantial initial investment, deserves a detailed preliminary study and thorough analysis of all basic factors, in order that full advantage may be taken of recent developments and improvements in combustion equipment. It is also desirable that the fuel buyer have increased latitude in the selection of coal during the entire period in which this equipment will be in operation, instead of suffering continued restrictions caused by a poor and hasty choice of apparatus.

A detailed study based on fuel-engineering principles should precede the selection of combustion equipment. The average buyer and local plant engineers are too busy with everyday problems to give full consideration to the basic factors of heat release, furnace volumes, combustion rates, furnace temperatures and their relation to the physical properties of the competitive fuels available, which can be adapted to the load conditions of the new steam plant. There is too great a tendency to shift this responsibility to the equipment manufacturer and the equipment offered is in many cases placed on a simple price-competitive basis with little or no thought being given to operating economies which can be effected for many years by an initial installation permitting greater latitude in the selection of coal. A reasonable premium in first cost of the equipment is often justified in order that the buyer may not be handicapped by fuel buying restrictions which are not at present anticipated.

There are few plants in this country today which have been designed and installed to give the purchaser this latitude in coal selection. It is very unfortunate that plants are being designed and erected every day that will place many restrictions on the coal consumer for the next twenty years, and it is the purpose of the writer to suggest in a general way, the procedure to be followed in order that proper consideration may be given to the inseparable relationship between the coal-burning equipment to be installed and the coals which can be successfully used. The consumer should be in a position to have several producers from more than one district competing for his coal business.

I am wondering if it is realized how little cooperation there is between the separate interests that are vitally concerned in this problem of the successful and economical operation of bituminous coal-burning equipment. It would seem that any installation, regardless of size, deserves complete cooperation, from its first inception, between the consumer's engineers, the general consulting engineer, the fuel specialist, the manufacturer of equipment and the coal producers who will be in position to supply the plant. If any of these interests are omitted from consideration, and their recommendations are not available for guidance, and if there is no cooperation between these various parties, it is quite likely that the coal consumer will be saddled for years with steam-generating equipment or a combination of units that will be improperly related to the available fuels.

In order to provide a clear conception of the cooperation that is desirable between those concerned in the power plant field, I will outline their general functions and basic responsibilities. First, we have the consumer's local engineering and purchasing staff, responsible to the management for the cost of operation of the plant. These individuals should be sufficiently informed so as to recognize excessive steam or power costs caused by inadequate, inefficient or relatively obsolete equipment, and realize that existing equipment, operating at 50 to 60 per cent efficiency can be replaced by modern equipment with efficiencies of 80 per cent and above. They should also know that when the plant requires premium coals, low in sulphur, low in volatile or with a high ash-

*Abstract of a paper presented at the Eighteenth Meeting of Fuel Engineers held under the auspices of Appalachian Coals, Inc., at Cincinnati, O., March 22, 1937.

fusion temperature, the price paid is seldom justified by the heat value and that other coals are available with less favorable burning characteristics for the average equipment, carrying much lower delivered cost on a Btu basis than the coal now used. They must be aware that they are unable to take advantage of fuel bargains and are often restricted to coals from one or two mines, simply because of the limited ability of their plant equipment.

What the Local Engineers Should Know

This local personnel must have a general knowledge of the new developments in the equipment field; they should know of the fundamental causes of coal price differentials; that production costs in some fields are much lower than in others, and that seam conditions in certain fields are conducive to low cost mining, whereas, in other fields expensive mechanical cleaning and special preparation must be provided in order to make the coal commercially acceptable. They should also recognize some of the conditions which are peculiar to the bituminous coal industry because of overproduction and lack of organization, and must anticipate that eventually these factors causing depressed prices, will be rectified and that coal selling prices will be more closely related to the production costs at the mines.

It will naturally be impossible for the local plant personnel to be experts upon any of these matters regarding which they should have only a general knowledge. They have other responsibilities and must depend upon experts and the specialists for final advice.

In describing the functions and responsibilities of the consulting engineer, it would seem that, to use a medical analogy, he may be classed as a general practitioner, who is either retained by the consumer on an annual basis to keep the power plant patient fit or who is retained on a temporary basis when the need for a major operation becomes necessary.

Many of the consulting engineering firms are specialists in the design and construction field. They should be the neutral advisors with a wide knowledge of the solid, liquid and gaseous fuels which are available to their industrial client. When they are retained for the design and construction of a new steam generating plant, one of their primary ambitions should be to see that the customer has a wide latitude in the selection and utilization of coals from the various fields available and that they will continue to secure not only efficient operation, but economic results for many years in the future.

The consulting engineer's first consideration should be a coal study, which should be comprehensive in its analysis from the standpoint of the relative delivered cost of coals under present market conditions and should also include a forecast on future relationship of market price levels. The next job for the consulting engineer will naturally be to prepare, in cooperation with the local engineers, a plant study involving steam requirements and load conditions. When all of these basic data are available, he will be able to submit specifications to manufacturers for combustion equipment that will meet the client's needs under present conditions and provide sufficient coal application flexibility for continued economical operation under new or changed price relationships which may alter the competitive fuel picture.

This coal study is the first and most important basic factor involved in the selection of the new equipment or governing an alteration that may be made in existing equipment to secure greater capacities or lower costs. It should be prepared by an expert in this particular field, the fuel consultant. There are several firms of fuel engineers in this country who devote their entire time to advising consumers on their everyday buying and also on the relation of available equipment to the best fuel values obtainable. It would seem that the advice of these particular specialists should be sought not only by the consumers but also by the general consulting engineers and the combustion equipment manufacturers when power plant projects are being prepared. Some firms do not employ a fuel consultant and for this reason the benefit of their advice and wide experience in fuel application matters is omitted from consideration in many new projects. Too often the coal study is a secondary matter and the recommendations of the poorly informed or inexperienced in the problem of economical fuel utilization are incorporated into the design and selection of new equipment and the usual result is, limited application of coal and inferior economic operating results for many years.

The fuel consultant should be intimately familiar with all the coals that are competitively available to the plant under consideration; he should have an intimate knowledge of the analytical quality and burning characteristics of these coals and the sizes in which they are available, and the prices at which they can be purchased. The competent fuel specialist will also have a fund of information about the various coal fields, the seams from which coals are being commercially produced, and the quality of coal that is being shipped from each mine by the various operators. He will also know the reliable operators who exercise great care in preparation to maintain uniform quality standards in spite of irregular seam conditions.

It is still true that "the final proof of the pudding is in the eating," but the fuel consultant can save the plant an extensive testing program by first relating the equipment to the best coal values available and then picking out two or three coals for final testing where actual experience has not indicated a preference. With a properly designed plant, these two or three best coals can be used for backlog supply and temporary spot bargains can be utilized to effect further savings.

Designing for Cheaper Coals

Manufacturers of combustion equipment must become coal conscious. Instead of worshiping efficiency, they must begin to recognize that some manufacturers are designing units to utilize the cheaper grades of coals possessing what were previously considered to be unfavorable burning characteristics. These coals can now be burned with high efficiency and the same reliability as was previously possible with the coals with premium characteristics. Too many plants are of the "prima donna" type. There is usually some restriction placed on the selection of coal—possibly the moisture cannot exceed 4 per cent, smokeless operation may not be possible with over 25 per cent volatile, 10½ per cent ash cannot be used because of certain limitations, and everybody is familiar with the restricted use of coal with a 2000 F fusion because of slagging or clinkering troubles, and in some cases the fusion is limited to 2450 F.

The prices paid for coarse sizes and special preparations are seldom justified by the increase in heat value.

Today, the bituminous coal producer has a new obligation to customers and prospects. The company with which the writer is connected has gone so far as to provide a fuel consultation service that is available to all of its customers and to those associated with the problem of coal utilization. Years ago coal producers began by shipping coal as run of mine only and it was used in whatever shape or condition that nature and handling abuse provided. As soon as mechanical combustion equipment of very crude construction and limited ability appeared, producers began to develop special sizes for securing acceptable results. During these early stages of industrial development, the small sizes of slack were considered worthless byproducts and dumped in the river, used to make roads, given away or disposed of in any way to get rid of them. Some of the manufacturers began to realize that special designs could be developed for the utilization of these waste byproducts and today we find that the demand for the small sized coals is so great and the market for the coarse sizes is declining to such an extent that the price of slack is gradually reaching a run of mine basis and the premiums that are being paid for coarse sizes are rapidly decreasing. The old law of supply and demand is still in control of the price relationship between the various sizes of coal. The day is fast approaching when slack will bring a run of mine price and the coarse sizes will be crushed in greater quantity than is now being done, to supply this increasing demand for small sized coal for mechanical fuel-burning equipment.

Some of the examples of special preparation and sizing that producers have found necessary to develop for the successful operation of mechanical fuel-burning equipment will be cited. Where formerly only run of mine was marketed, now it becomes necessary to make slack sizes in varying sizes from $^1/_8$ to 1 in. Nut-slack is now produced in a variety of sizes from 1 to 2 in., or above. Special sizes from which fine coals are removed are necessary for satisfactory operation on other equipment of limited ability, consequently the producer now has a pea coal possibly $^1/_4 \times {}^3/_4$ in.; a stoker size of $^1/_2 \times 1$ in.; a nut size of 1×2 in.; or an egg size of 2×4 in. or 3×5 in. Some of our "prima donna" hand-fired plants need a 2-in. coal or a 4-in. lump instead of run of mine. Some of our domestic users insist upon a 5-in. lump or an 8-in. lump. On top of some of these special sizes, we have special treatments for dustless purposes—calcium chloride, oil, petrolatum, etc., all adding to the cost of preparing coal for shipment.

It should be mentioned here that equipment which will provide the utmost in flexibility in one market can be a poor selection for a different market. The combustion equipment prospects are so numerous for the replacement of old hand-fired apparatus, that almost any variety mechanical unit will show a saving. The real secret is to secure the ultimate in savings when improvements are made, otherwise 50 per cent of the useful economic life of the new equipment may be unknowingly gone the day it is placed in service.

Special preparations which have been squirted on coal, almost without exception, are not justified by any increase in heat value—if the heat value increased in proportion, then these special preparations would not be a wasted expense to the consumer. Naturally, we will have to use these special preparations and sizes as long as we have these old plants with us. The science of burning coal has certainly developed to such a degree that we should have our eyes wide open when we buy new equipment. The old plant has reached the economic stage where it is necessary to revitalize and rebuild. Don't be penny-wise and save the cost of the trained experts' advice or select on the basis of first cost.

[Mr. Payne's analysis of the situation, from the viewpoint of the coal producer is most interesting, and his suggestions for preliminary studies of available coals and closer cooperation between all parties concerned are well taken. It is questionable whether his views on the use of premium coals will find complete agreement from the operating standpoint. Local conditions and operating requirements are often such as to warrant, in the opinion of many, the burning of better grade coals, particularly those low in sulphur, when the cost of labor, maintenance and outage is balanced against the price differential. Discussion of these points from the operating viewpoint would be welcome.—EDITOR.]

Ford to Add Another High-Pressure Unit

While the April issue, containing the results of tests on the million-pound per hour unit No. 5 at the Rouge Plant of the Ford Motor Company, was on the press, announcement was made of plans to install another similar high-pressure unit in this plant to replace the remaining original low-pressure boiler No. 7. Another 110,000-kw turbine-generator has also been ordered. This will bring the rated steam capacity of the Rouge boiler plant up to 5,200,000 lb per hr, 3,200,000 lb of which will be in 1400 lb steam. On the units already installed the rated capacities have been considerably exceeded so that the total maximum capacity will be greater than this figure. The addition of the new turbine-generator will bring the generating capacity up to 435,000 kw. Not only is this the largest industrial power plant in the world but it has the greatest capacity in high-pressure steam of any station, industrial or central station.

The new steam generating unit will be similar to No. 5, except that the steam temperature will be slightly higher, namely 925 F. It will be a C-E double-set, five-drum boiler with plate-type air heaters and economizers, pulverized-coal fired and designed for 1400 lb pressure.

The new turbine-generator will be of the G.E. vertical-compound type, practically a duplicate of the second unit which went into service last summer. The 1800-rpm high-pressure turbine and generator will be mounted on top of the 1800-rpm double-flow, low-pressure element and hydrogen cooling for the generators will be employed. Hydrogen cooling reduces windage losses to one-tenth of that with air and this results in an improvement in the generators of from 0.6 to 1.1 per cent.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Flow in Steaming Tubes Arranged in Parallel

In the March 1937 issue of *Archiv für Wärmewirtschaft*, Dr. Heinrick Vorhauf, of Berlin, tells of some experiments in the flow of steam in tubes arranged in parallel circuits.

Five tubular steaming coils of the same length arranged in parallel, were substantially uniformly heated by a gas burner. The coils were separated from each other by asbestos board forming five equal regulatable gas passes. The heat absorption of each coil was measured by pumping water through it without steaming, and was found to be about 8730 Btu per hr and varied only 5 per cent above and below this value. Without such regulated gas passes a 25 to 30 per cent variation in heat absorption occurred even with apparent uniform distribution of heat to all coils, showing how difficult it would be to obtain uniform heat distribution over the walls of a furnace.

The water was pumped from and delivered to an open tank and the steam formed within the coils escaped to the atmosphere. The discharged excess water could be measured and the uniformity of the discharged steam-water mixture observed.

Water Distribution without Nozzles

Tests were first made without nozzle restrictions in the tubes. The water circulation through all coils was uniform when no steam was being made within any of them. When steaming, the individual water discharge of the coils was measured and recorded in terms of the steaming capacity of each coil. The chart shows the lack of uniformity in water flow through the coils. With a combined circulation equal to ten times the steam output of all coils, coil No. 3 received at first thirty-two times as much water as its steam output, while coils Nos. 1, 2, 4 and 5 received but two to four times as much. Note that one coil did not continuously receive such excess water while the others received less, for at times the excessive water flow to one coil was suddenly reduced or even ceased (see reading 6 of tube No. 3). This may be attributed to unequal heating of the coils.

A fifteen-fold increase in circulation merely increased the circulation within one coil, the remaining coils receiving no more water than before, and further increases even to forty-fold showed no uniform distribution of water to all coils although the number of coils receiving more water increased. When circulating but three or four times the steam output, the discharge of a single coil was irregular in that gulps of water discharged in large quantities over short periods, were followed by a discharge of only steam.

Distribution with Nozzles

When nozzles were employed within the entrance of the coils, there was introduced a resistance equal to about 1 atm when circulating eight times the steam output. The sizes of nozzles for each coil were equal.

Readings 59 to 77 on the chart show uniformity of distribution to all coils down to as low as a five-fold circulation. With lower circulations pulsations occurred because the resistance through the nozzles became too small. When using nozzles the discharge of steam and water from all coils was uniform.

It was found that with nozzles and a five-fold circulation, the power consumption was about one-seventh that without nozzles and a forty-fold circulation.

Pressure Drop within a Single Coil

Measurements of pressure drop from inlet to outlet of one coil were taken without nozzles for increasing values of circulation. Below five-fold circulation, pulsations were present causing pressure drop variations; above five-fold circulation the pressure drop rose to a maximum at eight fold, then fell to a minimum at about twenty-two fold and thereafter rose again. This characteristic ex-

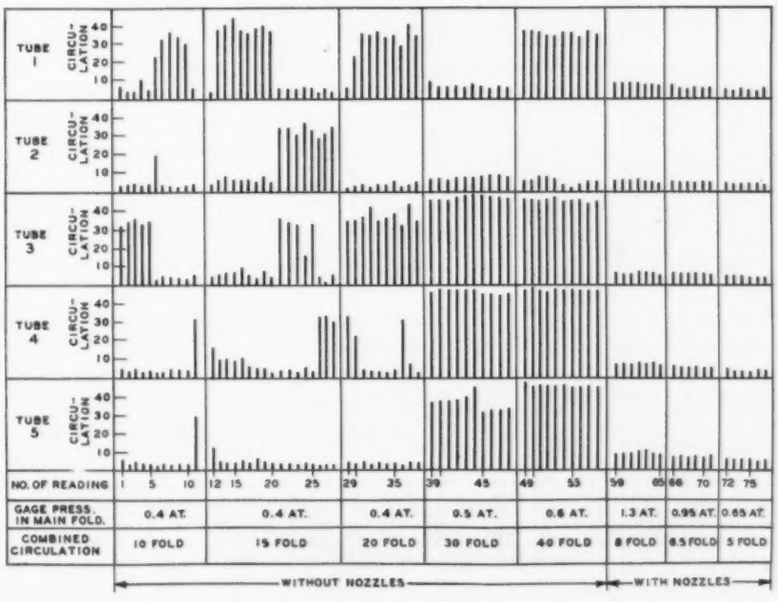
TUBE 1
TUBE 2
TUBE 3
TUBE 4
TUBE 5
CIRCULATION
40
30
20
10
NO. OF READING
1 5 10 12 15 20 25 29 35 39 45 49 55 59 65 66 70 72 75
GAGE PRESS. IN MAIN FOLD.
0.4 AT. 0.4 AT. 0.4 AT. 0.5 AT. 0.6 AT. 1.3 AT. 0.95 AT. 0.65 AT.
COMBINED CIRCULATION
10 FOLD 15 FOLD 20 FOLD 30 FOLD 40 FOLD 8 FOLD 6.5 FOLD 5 FOLD
WITHOUT NOZZLES
WITH NOZZLES

Chart showing flow in different coils

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plains why at a certain excess pressure within the manifold and with coils in parallel and without nozzles, the water will either flow through a coil in pulsations or will jump up to a thirty-fold or greater flow.

[Although of great value in visualizing the performances of the flow within coils in parallel, the above experiments were made at atmospheric pressure and should not necessarily be used as criterions for the performances of the flow through heating surfaces at higher pressures when connected in parallel.

At higher pressures than atmospheric the ratio of the volume of steam to water drops rapidly with the result that, for a given percentage by volume of steam allowable at the tube outlet of the heating surface, the amount of circulated water in units of steam output (i.e. pounds of water circulated per pound of steam generated) falls off very rapidly. As the pressures rise there, less circulated water is required and the evils of one tube taking excess water to the detriment of the remaining tubes in a parallel circuit of a heating surface, become less. At the usual operating pressures and with heating surfaces provided with sufficient downcomer and riser connections, the necessity of forced circulation and resistance nozzles to assure proper circulation of parallel circuits has not been necessary. However, in long coils of small diameter tubes where forced circulation becomes necessary, such resistances within the tubes of parallel circuits may become necessary.—EDITOR]

Turbine Experience on the Queen Mary

Speaking before the Spring Meeting of the Institution of Naval Architects (Great Britain) on March 17, 1937, S. J. Pigott reviewed certain special mechanical features of the Queen Mary and related some early experience with the turbine blading and the main turbine nozzles. Following are excerpts from his paper as reported in the April 2 issue of *The Engineer*.

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It was concluded that these fractures had occurred during the over-speed trials from the synchronizing of the frequency of steam jet impacts on the blading with the natural periodicity of vibration of the blading. This blading was subsequently replaced with heavier and more rigid sections during July and has since functioned satisfactorily.

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The boilers are reported to have functioned with entire satisfaction.

Data on the Grid

A recently published report of the Electricity Commissioners (Great Britain) for the fiscal year ending March 31, 1936, is quoted in *Engineering* of April 23, 1937. It appears that during the period under review 632 undertakings were engaged in the business of public electricity supply. Of these, 64 were supplied from their own generating stations, 157 both generated and took a bulk supply and 411 took a bulk supply only. Of the generating stations, 222 were publicly owned and 176 privately owned. The total installed capacity was 8,099,870 kw, over 80 per cent of which was installed in 131 stations. The station of greatest capacity was Barking, with 387,500 kw. Steam turbines accounted for 95.21 per cent of the total capacity involved. Seven different frequencies are in use but 93.5 per cent of the total output was at 50 cycles. The total evaporative capacity of the boilers installed was 91,846,431 lb per hr distributed among 2111 units with outputs ranging from 2000 lb to 256,000 lb per hr. There were fifty-five different working pressures ranging from 100 lb per sq in. to 1100 per sq in. The total amount of electricity sold was 15,049,400,000 kwhr.

Coal vs. Oil for Merchant Ships

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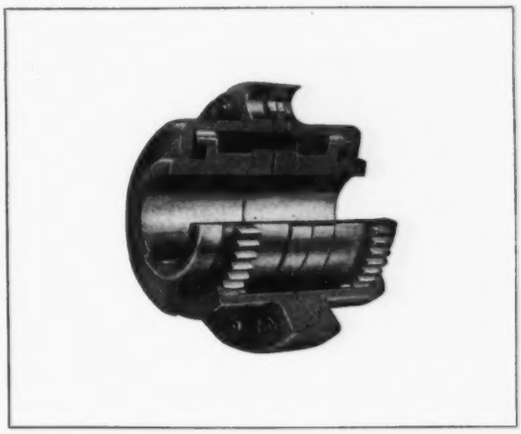

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plains why at a certain excess pressure within the manifold and with coils in parallel and without nozzles, the water will either flow through a coil in pulsations or will jump up to a thirty-fold or greater flow.

[Although of great value in visualizing the performances of the flow within coils in parallel, the above experiments were made at atmospheric pressure and should not necessarily be used as criterions for the performances of the flow through heating surfaces at higher pressures when connected in parallel.

At higher pressures than atmospheric the ratio of the volume of steam to water drops rapidly with the result that, for a given percentage by volume of steam allowable at the tube outlet of the heating surface, the amount of circulated water in units of steam output (i.e. pounds of water circulated per pound of steam generated) falls off very rapidly. As the pressures rise there, less circulated water is required and the evils of one tube taking excess water to the detriment of the remaining tubes in a parallel circuit of a heating surface, become less. At the usual operating pressures and with heating surfaces provided with sufficient downcomer and riser connections, the necessity of forced circulation and resistance nozzles to assure proper circulation of parallel circuits has not been necessary. However, in long coils of small diameter tubes where forced circulation becomes necessary, such resistances within the tubes of parallel circuits may become necessary.—EDITOR]

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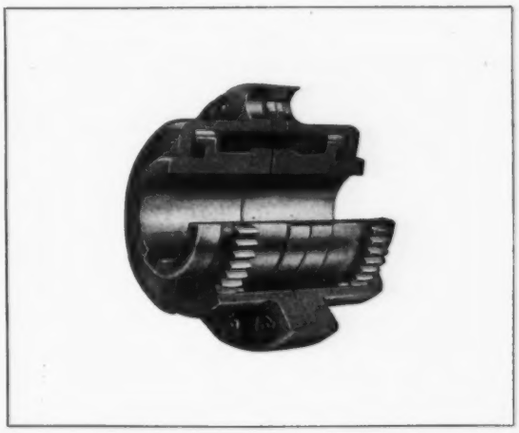

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clear economic advantages over motorships of the same size and speed.

4. For large fast liners, the oil-fired boiler represents well-established practice, but vessels in this category do not constitute more than a small percentage of the total tonnage.
5. The reliability and efficiency of modern steam machinery are insufficiently appreciated so that to some extent the preference for diesel propulsion presents a "fashion" rather than the result of economical facts.

A committee was appointed to inquire further into the comparative values of coal and oil for merchant ships.

German Views on Turbine Types

A. Rosenlöcher, in the January 2 issue of *De Wärme*, discusses the various factors involved in different types of steam turbines. Leakage loss, he points out, is less in impulse than in reaction turbines, hence the former has some advantage where smaller quantities of steam are handled. As to leaving losses, these are of more importance in machines operating on base load than where peak load service is concerned. For a given pressure drop, reaction turbines require a greater number of stages and, in order to reduce leakage losses, longer blades must be employed with accompanying smaller stage diameters. The author further observes that unless large nozzles are required to handle large quantities of steam, there is no point in multistage construction for back-pressure turbines. Where extraction of steam is required, German practice leans to two-cylinder construction. He favors the use of reduction gearing and high turbine speeds for back-pressure turbines of small and medium capacities.

Hydrogen Penetration through Steel

Ordinarily it is considered that a metal container is gas-tight, provided its seams are tight. Hydrogen, the lightest gas, however, slowly escapes through metal, even of appreciable thickness. In his paper before the American Chemical Society on "Diffusion of Hydrogen from Water through Steel," Dr. F. J. Norton, of the General Electric Research Laboratory, pointed out that in high-pressure steam boilers, at a temperature of about 575 F, water and iron react to produce iron oxide and hydrogen. The iron oxide forms black scale on the tubes of the boilers; some of the hydrogen escapes as gas within the tubes, some combines with oxygen dissolved in the water, and the rest diffuses through the steel. The reaction occurs even at room temperature, but is greatly speeded up as the pressure and temperature are increased.

A detector-amplifier-triode metal vacuum tube was used by Dr. Norton for observing the hydrogen flow. It is a small, evacuated volume within steel walls, and in it are a plate, grid and filament—the elements used in ionization gages to measure gas pressures. In the circuit, the grid is the most negative and hence positive ions flow to it. The number of positive ions is proportional to gas pressure, so the grid current is a measure of gas pressure.

The metal vacuum tube ordinarily has a coating of protective paint, and this was sandblasted off for most of the experiments. The tube shell was then dipped into water at different temperatures and for different lengths of time, and the grid current measured. The measurements showed that, at 78 F, hydrogen entered through the 30-mil steel shell at a rate of one-tenth of a micron per hour which is about one cubic inch of gas per thousand years. The gas which passed through the steel was analyzed and found to be extremely pure hydrogen.

Addition of one-tenth of one per cent of sodium chromate to the water, known to inhibit corrosion, was found to stop the penetration of hydrogen through the steel. Dr. Norton found it impossible to measure any penetration, and his equipment was capable of measuring as little as one cubic inch of gas per hundred thousand years. Various coatings were applied to the tube and the rate of diffusion determined. The regular paint as applied to the radio tubes was found to be the best protection. Various other coatings lowered the rate of diffusion somewhat, but a few coatings, such as zinc, or porous copper plating, or sodium silicate, caused increased diffusion. Stainless steel was found to give a very much lower rate than ordinary steel, and tubes with composite walls of different metals were found to have different diffusion rates.

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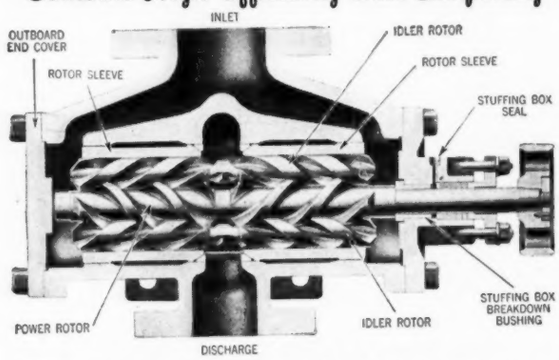

THE operating parts consist of the central or power rotor, flanked by the two sealing rotors, these three rotors being the only moving parts. This very simplicity insures freedom from trouble in operation. *Removal of the coupling half and the outboard end cover gives access to all working parts,* without disturbing the suction and discharge piping or the prime mover. The novel design of the rotors, the absence of pilot gears and the elimination of all but one stuffing box, each contributes to high efficiency, thus saving power.

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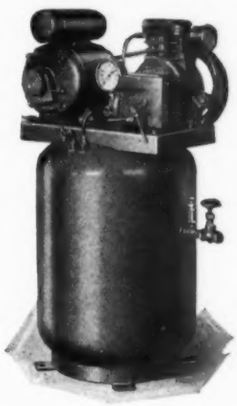
NEW EQUIPMENT

Air Compressors

Ingersoll-Rand Company, Phillipsburg, N. J., has brought out a new line of fractional horsepower single-stage air compressors in $^1/_4$ and $^1/_2$ hp sizes. They are equipped with a seamless steel tank and have automatic start and stop control. When furnished for single-phase current they are equipped with a brushless capacitor-type motor and a built-in automatic protection switch giving underload and overload voltage protection. They are



rated at 150-lb maximum pressure but may be set for lower pressures, and vertical or horizontal tanks are furnished in 2.4 and 4.6-cu ft capacities.

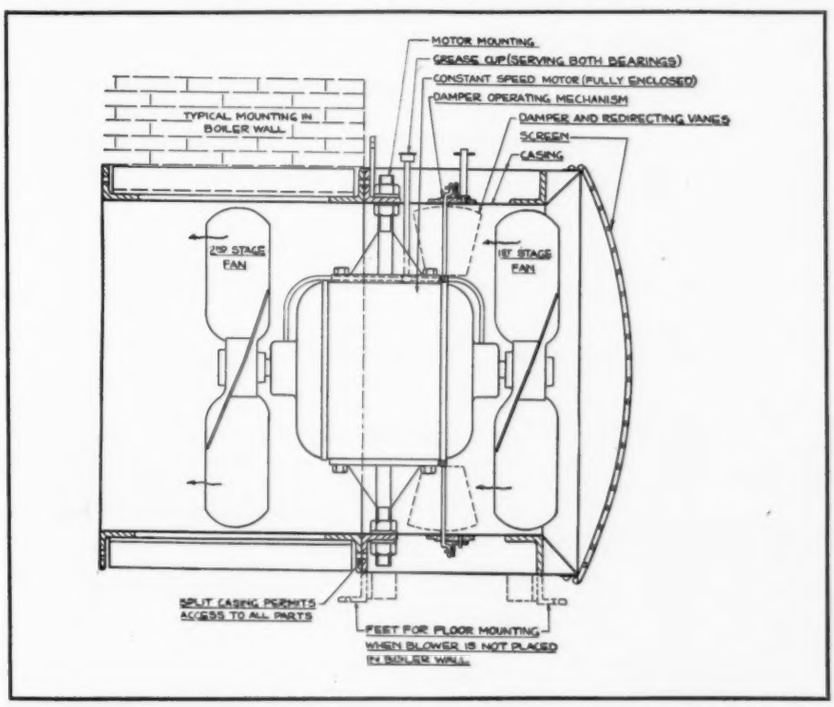
Blower Unit

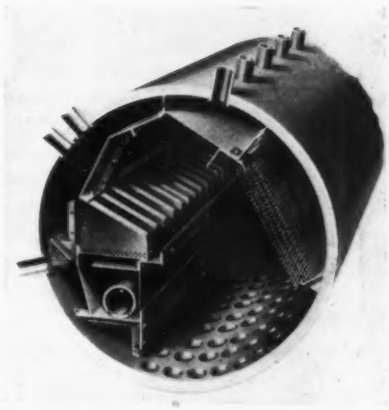
A new design of forced-draft blower has been developed by the L. J. Wing Mfg. Co., New York, consisting of a constant-speed motor, with double extended shaft, two propeller type fan wheels, one mounted on each end of the extended shaft, an integral damper control and an air-redirecting mechanism built in between the two fan wheels. The entire assembly is contained within a cylindrical casing. The integral damper mechanism permits close control of the air delivery over a wide range with decreasing power. The control of the dampers may be effected manually or automatically by employing any of the standard automatic draft controls. Built for pressures up to 6 or 7 in. of water, the blower may be applied to hand-fired, stoker-fired or oil- and gas-fired boilers or for the secondary air supply to pulverized-coal-fired units.

Bubble-Type Steam Washer

A steam washer has been developed by Combustion Engineering Company, Inc., New York, which functions on the principle of removing entrained solids from the steam by forcing it to bubble through clean feedwater. This washer has been subjected to long and extensive tests under regular operating conditions in one of the large power stations, and as a result of the satisfactory performance a number of subsequent installations have been made.

Referring to the illustration, the feedwater enters the trough at the lower left through the longitudinal perforated pipe and spills over the notched weir. Mounted over the trough are a series of compartments, or hoods, open at the bottom and left and having perforations near the bottom of the side walls. These hoods are


MOTOR MOUNTING
GREASE CUP (SERVING BOTH BEARINGS)
CONSTANT SPEED MOTOR (FULLY ENCLOSED)
DAMPER OPERATING MECHANISM
DAMPER AND REDIRECTING VANES
SCREEN
CASING
TYPICAL MOUNTING IN BOILER WALL
2ND STAGE FAN
1ST STAGE FAN
SPLIT CASING PERMITS ACCESS TO ALL PARTS
FEET FOR FLOOR MOUNTING WHEN BLOWER IS NOT PLACED IN BOILER WALL

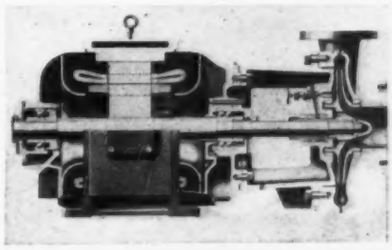


joined together by plates at the left and over them is bolted a continuous plate which extends to the top of the drum. Thus the steam entering the drum through the tubes at the left is compelled to pass into the hoods and out through the apertures, and bubbles through the feedwater, in which operation the entrained solids are removed. The actual washing of the steam is obtained not alone by bubbling through the water but also by the violent mixing of steam and water between the elements as created by the velocity of steam through the perforations. The construction is such as to prevent comingling of the feedwater with the water in the drum. The screen at the right is for the removal of moisture that may be carried along with the steam.

The washer is so located as to leave space for ready access for cleaning without removing it from the drum. However, should it be desired for any reason to remove the washer this may be readily done in sections, as the parts are bolted together.

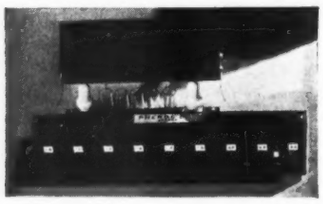
Motor-Mounted Pump

A new line of motor-driven centrifugal pumps in capacities from 5 to 1200 gpm and heads of 10 to 230 ft has been announced by the De Laval Steam Turbine Company, Trenton, N. J. Referring to the illustration, the pump is mounted upon the end bell of an electric motor, the two forming a compact and self-contained unit with a single shaft and two bearings. The pump casing is of cast iron while the impeller, wearing ring and shaft sleeve, stuffing-box gland and lantern ring are of bronze. All the pump parts may be removed without disturbing the motor. The unit can be installed with its shaft in any plane and does not require a special foundation.



Phosphate Slide Comparator

A phosphate slide comparator, for determining the phosphate content of boiler water has recently been developed by W. A. Taylor & Co., Inc., Baltimore. The outfit consists of a slide and a base, molded from bakelite. The former contains nine color standards, representing 5, 10, 20, 30, 40, 50, 60, 80 and 100 ppm of phosphate as PO_4 and eight ampoules of distilled water, the color standards alternating with the ampoules of distilled water. The base has



a slot in which the color standard slide is moved back and forth, two vials for reagents and five test tubes. Behind the three central test tubes is a piece of etched glass and a top protects the vials and test tubes when the set is not in use.

In making determinations a sample of the boiler water is treated with molybdate and stannous chloride reagents in a special mixing tube. A blue color develops and its intensity is proportional to the phosphate present. Maximum color formation develops in about one minute. The middle test tube is filled with the test sample and those on both sides are filled with the unheated boiler water. The slide is then moved until a color match is obtained or until that of the test sample falls between the colors of two consecutive standards. The phosphate content of the water is then read off from the values on the slide. The outfit is designed so as to avoid interfering reactions with constituents other than phosphates.

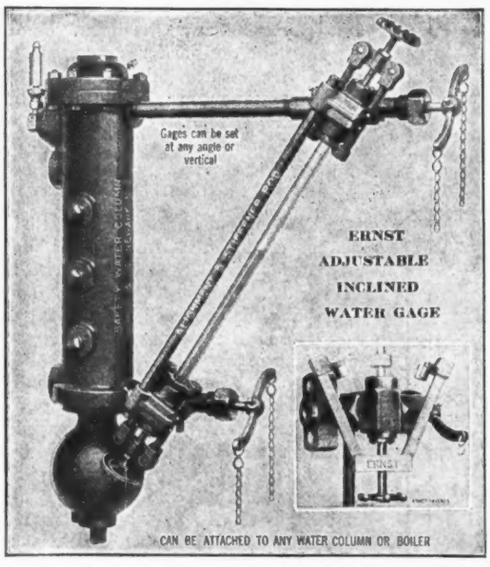
Steam Turbines for Auxiliary Drives

For driving general purpose machinery in industrial plants and auxiliary equipment in generating stations, a new and improved line of Type "C" turbines has been brought out by Westinghouse Electric and Manufacturing Company. The turbines are of the impulse type having one pressure and two velocity stages. They are built in capacities ranging approximately from 5 to 500 horsepower, at turbine speeds of 1000 to 5000 rpm, suitable for use with steam pressures up to 650 lb gage and for total temperatures up to 750 F. They may be operated either condensing or non-condensing with rotation in either direction. These turbines are particularly adapted to driving pumps, forced- and induced-draft fans, compressors, pulverizers and similar apparatus, either direct-connected or through gear or belt drive.

The casing consists of a base and cover bolted together at the horizontal joint. Depending on the steam conditions it will be of cast iron or steel. All pipe connections are made to the base so that the cover may be readily removed for inspection of internal parts and the base is arranged so that the exhaust opening may be located on either side to best suit the individual conditions.

The turbine speed is controlled by a centrifugal weight governor mounted on the end of the rotor shaft and connected through a lever to the steam admission valve. This governor is designed for simplicity combined with maximum sensitivity and power, which qualities are obtained by providing three weights instead of the usual two.

The rotor is supported in two bearings which are split horizontally and lined with tin-base babbitt. Either bearing may be removed without raising the cylinder cover or rotor. One of the bearings is babbitt-faced at both ends and acts as a combined thrust and journal bearing. The rotor shaft carries two adjustable collars which locate the rotating element axially.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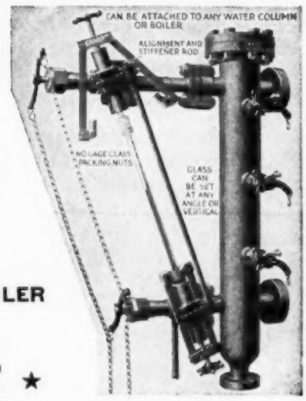
VERTICAL OR INCLINED
MADE TO FIT ANY COLUMN OR BOILER



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ERNST "Split Gland" Gages
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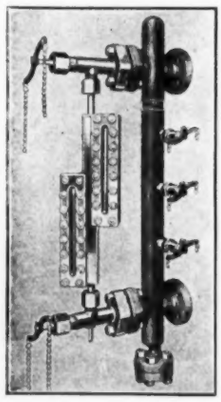
ERNST Vertical Glass Water Gages
ERNST High Pres. Composition Gaskets
ERNST Gage Glass Guards ERNST Illuminators
ERNST Safety Gage Glasses



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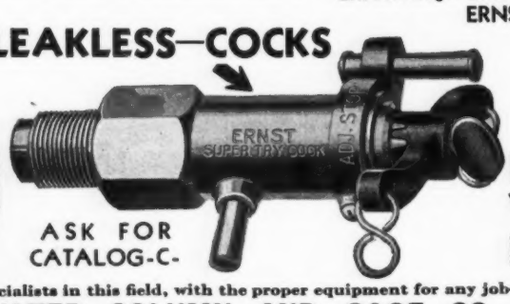

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National Board of Boiler Inspectors to Meet in New York

The Eleventh General Meeting of the National Board of Boiler and Pressure Vessel Inspectors will be held at the Hotel McAlpin, New York, N. Y., May 24, 25 and 26. This Board was organized in 1919 for the purpose of securing uniform approval of specific designs of boilers and pressure vessels through the adoption by various states and cities of one code of rules and of one standard stamp to be placed on boilers and pressure vessels constructed in accordance with such rules.

There will be morning and afternoon sessions on each of the three days. All of the sessions will be open to those interested; registration will be required but there will be no charge therefor.

Major changes in the construction and design of boilers and pressure vessels are being made, together with the development of new materials contemplated in their construction and these changes and new materials are the basis on which the program for this meeting has been developed. The subjects to be discussed are of utmost importance and interest to engineers, manufacturers and operators of these vessels and the papers will be presented by foremost authorities on the various subjects. A partial list of these subjects is as follows:

"Welding Problems in connection with High Tensile Strength Low Alloy Steel," by Dr. J. C. Hodge, Babcock & Wilcox Company

"Use of Non-Ferrous Alloys in the Construction of Pressure Vessels," by J. J. Vreeland, Chase Brass & Copper Company

"Use of Ferrous Alloys in the Construction of Pressure Vessels," by W. R. Grounow, Allegheny Steel Company

"Latest Developments of Steam Generating Plants," by John Van Brunt, V. P., Combustion Engineering Company, Inc.

"Design and Testing of Safety Valves," by Prof. Paul Bucher, Ohio State University

"Welding of Power Plant Piping," by H. LeRoy Whitney, M. W. Kellogg Company

"The Non-Destructive Inspection of Welded Pressure Vessels," by Dr. Comfort A. Adams, Consulting Engineer

"Developments of Forced Circulation Boilers," by H. B. Oatley, V. P., The Superheater Company

"Water Problems in High-Pressure Boilers," by S. T. Powell, Consulting Engineer

"Welding of High Strength Copper Alloys," by M. Powell, The Whitlock Coil Pipe Company

"Operating Problems of Modern Large Steam Generating Units," by E. H. Krieg, American Gas & Electric Company

"General Problems in the Repair of Welding of Boilers, Pressure Vessels and Pipe Lines," by H. H. Mills, Boiler Inspector, Detroit

"General Problems of Welding in Light of Today's Experience," by James Partington, American Locomotive Company

"Welding of Alloys," by W. B. Miller, Union Carbon and Carbide Research Laboratories

"Necessity of Maintaining High Standards for Welded Vessels," by A. C. Weigel, Combustion Engineering Company, Inc.

"Safe Operation of Low-Pressure Steam Boilers and Hot Water Vessels," by J. P. H. de Windt, Mgr. Boiler & Machinery Div., National Bureau of Casualty & Surety Underwriters

"Avoidance of Furnace Explosions," by E. G. Bailey, V. P., Babcock & Wilcox Company

A special committee has prepared an exhibit which will be of great interest, showing among other things, examples of sound and defective welding, examples of failures experienced in operation, and examples of new construction and design of boilers and pressure vessels.

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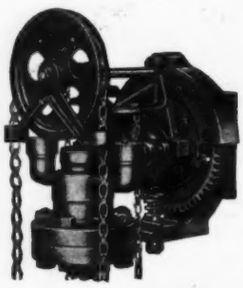

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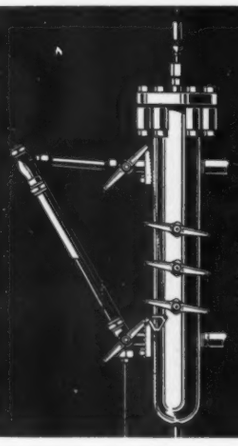

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